Essays on futures contracts as a feeder cattle price risk management tool

by

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Abstract

This thesis consists of two articles analyzing the feeder cattle futures contract as a price risk management tool. The first article implements transaction-level data and feeder cattle futures interaction terms in a hedonic pricing model framework to estimate optimal feeder cattle hedge ratios conditioned on the price of corn. This deviates from previous feeder cattle hedging literature, which typically employs aggregate weekly data and simple linear regressions of cash price against futures price to estimate hedge ratios. Hedging risk using corn-conditioned hedge ratios is compared to estimated hedge ratios that are not dependent on corn price. The second article again implements transaction-level data and a hedonic pricing model framework to evaluate whether feeder cattle basis risk has changed over time and to identify factors driving basis risk. The method developed in the second article differs from previous livestock basis risk assessments in that out-of-sample transaction price prediction errors are used to represent unexplained cash price deviations from feeder cattle futures price, or basis risk. Results from both articles indicate varying market conditions and animal characteristics have important impacts on the effectiveness of feeder cattle futures for price risk management in a heterogeneous market.

Table of Contents

List of Figures

List of Tables

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Article 1 – Conditional Feeder Cattle Hedge Ratios: Cross Hedging with Fluctuating Corn Prices

Introduction

Facing notable market uncertainty, feeder cattle producers commonly hedge cattle price risk using the CME Group Feeder Cattle Futures contract. However, feeder cattle being hedged often do not match contract specifications, deviating by sex, weight, frame score, or other factors affecting market values. As such, feeder cattle are often cross hedged. Cross hedging necessitates estimation of a hedge ratio to equate differences in cash and futures price movements. The price of corn has been an overlooked factor when estimating feeder cattle hedge ratios. The impact of corn price on feeder cattle hedge ratios is essential to consider because corn price is an important determinant of feeder cattle weight-price slides. For instance, as corn becomes more expensive, increasing feed costs, prices of lighter-weight cattle decrease relative to feeder futures prices and the resulting hedge ratio declines. The impact of changing corn price on weight-price slides makes feeder cattle hedge ratios conditional on corn price. Failure to adjust hedge ratios for changing corn price can lead to over- or under-hedging.

The main purpose of this study is to quantify feeder cattle hedge ratios conditional on varying corn price. In particular, we use transaction-level data to estimate hedge ratios conditioned on corn price across time for various cattle weights, sex, and geographical locations. In assessing hedge performance, we quantify financial risk faced by producers when hedge ratios fluctuate with corn price and compare to risk using feeder cattle hedge ratios not conditioned on corn price. The secondary purpose of this study is to determine if feeder cattle hedge ratios differ across time, sex, location, and weight. Understanding the impact corn price has on hedge ratios (and associated hedging performance) and how hedge ratios differ across time and animal characteristics enables producers to make more informed hedging decisions.

Results reveal hedge ratios for all sex and weight of feeder cattle in Joplin, Salina, and San Angelo followed the same general pattern, and were smallest in the early-2010s when corn price reached its peak. Estimated hedge ratios were substantially different across feeder cattle sex and weight, suggesting hedge ratios depend on cattle characteristics. Hedging risk for all locations followed the same general pattern, increasing from the late-2000s until peaking in 2015. Corn-conditioned hedge ratios did not statistically or economically significantly reduce hedging risk when compared to hedge ratios not dependent on corn price, meaning that estimated hedge ratios not dependent on corn are as effective in managing price risk even in the presence of fluctuating corn price.

Previous Studies

Numerous and substantial differences in feeder cattle characteristics often requires producers to hedge price risk of an underlying commodity without a direct futures contract. In these instances, a cross hedge, or taking a position in a different but related commodity, is appropriate (Anderson and Danthine, 1981). The relative movement in cash price of the off-contract commodity to the futures contract price is known as the hedge ratio. The hedge ratio is the ratio of the futures to cash volumes hedged to offset variability of the cash position value, or the dollar change in cash price per dollar change in futures price of the related commodity.

Hedge ratios can be estimated in numerous ways. Chen, Lee, and Shrestha (2003) demonstrates common alternative hedge ratio estimation approaches converge to the conventional minimum-variance hedge ratio (cash price changes regressed against futures price changes) if futures prices follow a martingale process and futures and cash prices are jointly normal. The estimation procedure used to calculate hedge ratios depends on the objective of the hedger, the type of hedge being placed, and underlying assumptions of cash and futures market distributional behavior (Witt, Schroeder, and Hayenga, 1987). For a risk-averse hedger placing an anticipatory hedge, a price-level model is appropriate as the current cash price (and associated changes in cash price) is not relevant to the performance of the hedge (Witt, Schroeder, and Hayenga, 1987). Hedge ratios generated from a price-level model are as statistically correct as other procedures and preferred for anticipatory hedges except when: the cash-futures price relationship is nonlinear in levels, the price-level equations display strong positive autocorrelation, and first-order autocorrelation occurs in the price-level model (Witt, Schroeder, and Hayenga, 1987). From a practical standpoint, hedge ratios estimated using transaction data, as in this study, necessitate use of price-level models.

The price-level method to calculate hedge ratios involves regressing cash price levels against futures price levels of a related commodity, with the hedge ratio being the regression coefficient. This method has been common in livestock hedging literature. Following the 1986 change in the CME feeder cattle futures contract from physical delivery to cash settlement, Elam (1988) implemented a price-level model to estimate hedging risk differences for Arkansas feeder cattle of varying weights and sex across the two contract settlement specifications. Schroeder and Mintert (1988) extended Elam's work, using price-level models to estimate feeder cattle hedge ratios across varying weights, sex, and market locations. Elam and Davis (1990) noted a traditional hedge, or a pound-for-pound hedge, is not generally the risk-minimizing hedge for feeder cattle that are a heavier or lighter weight than futures contract specifications. Estimated hedge ratios derived from their price-level models were greater than 1.0 for lighter-weight cattle because cash prices of lighter-weight animals were more variable than futures prices. Buhr

(1996) regressed finished Holstein steer prices against live cattle futures, using the estimated hedge ratios to assess hedging risk and determine hedging relationships for Holsteins compared to beef steers. Hedge ratios for Holstein steers did not differ significantly from 1.0 and cross hedging Holsteins with the live cattle futures contract generally did not result in significantly greater risk than hedging beef steers.

Previous literature has estimated feeder cattle hedge ratios using aggregate average prices, varying hedge ratios by location, weight class, sex, and season (e.g., Elam, 1988; Schroeder and Mintert, 1988; Elam and Davis, 1990). Other market and animal characteristics (corn price for example) have not explicitly been modeled into feeder cattle hedge ratios. Using aggregated data may yield correlation and regression coefficients exhibiting considerable bias relative to using disaggregated data (Clark and Avery, 1976). Feeder cattle are a heterogeneous commodity with transaction prices that vary in economically important ways across animal and lot characteristics (Zimmerman et al., 2012). With hedging performance depending on time-sensitive factors and the type of animal being hedged, the level of data aggregation employed in previous hedging literature may bias hedge ratios and hedging risk assessments of heterogeneous feeder cattle. Hedge ratios estimated using transaction-level data may differ in economically important ways relative to using average prices and aggregated animal characteristics. This study uses transactions data to estimate hedge ratios and hedging performance conditioned on individual lot characteristics and market conditions.

In addition to hedge ratio estimation, an assessment of hedging risk is important to consider. The typical approach to quantify risk associated with cross hedging has been the framework used by Elam (1988). Quantifying hedging risk is generally done by calculating the standard deviation of the difference between a net price and a target price of the hedge, with net price representing the actual price received from the hedge and target price representing the price the hedger expected to receive (e.g., Elam, 1988; Schroeder and Mintert, 1988; Elam and Davis, 1990; Buhr, 1996). This method provides a measure of hedging risk in the original units of measure—in our case of feeder cattle, dollars per hundredweight.

Procedure

The following price-level regression model has often been used to estimate feeder cattle hedge ratios:

(1) $$C_t = b_0 + b_1 F_t + e_t$$

where *C* is the cash price of cattle being cross hedged, *F* is the nearby feeder cattle futures price (or some proxy), *t* is time (week), b_0 is the intercept, b_1 is the hedge ratio, and *e* is a random error term. Equation (1) has typically been estimated separately for different feeder cattle market locations, sex, seasons, and weights (e.g., 100-pound categories) using aggregate price data.

Price variation across transactions could affect basis risk and/or hedge ratios. Hedonic premiums and discounts across feeder cattle transactions not related to price levels affect basis. For example, transaction lot size or location would be independent of overall fundamental feeder cattle market price level; price variation due to these types of variables result in basis variation. However, price differentials across feeder cattle transactions related to price level would cause hedge ratios to vary across transactions. Characteristics such as animal weight and sex may result in price differentials across transactions that are related to price level and, consequently, influence hedge ratios of individual lots. Several lot characteristics may affect hedging performance, so estimating hedge ratios using transaction prices instead of traditional weekly-average prices provides a more granular assessment. Therefore, we modify the traditional price-level model expressed in equation (1). To do so, we use a hedonic modeling framework to determine effects of market and lot characteristics on individual feeder cattle transaction cash prices and associated hedge ratios.

We fit hedonic pricing models to 10-year rolling samples of transaction data and use the resulting coefficients in hedge ratio calculations for the subsequent year in an out-of-sample fashion. The hedonic pricing models are estimated separately by sex and market location. Interaction terms in the hedonic models of select variables with feeder cattle futures price results in estimated hedge ratios dependent on lot characteristics and market conditions, detailed below. As such, each individual lot of feeder cattle has a unique hedge ratio that is a function of: 1) lot-specific sex and market location hedonic pricing model coefficients from the previous 10 years and 2) market forces and lot characteristics on the day the lot is sold.

To assess how changing corn price affects hedge ratios and associated hedging performance, we compare two different hedonic pricing models; one including corn price interaction terms that results in hedge ratios conditioned on corn price ("conditional") and another without the corn price interactions ("unconditional"). The unconditional hedge ratios are similar to feeder cattle hedge ratios published in existing literature, only estimated here using transactions instead of aggregated data.

Conditional Hedge Ratios

The conditional hedge ratio hedonic pricing model is expressed as:

$$PRICE_{it} = b_0 + b_1 FF_t + b_2 \frac{FF_t}{WT_{it}} + b_3 \frac{FF_t}{WTSQ_{it}} + b_4 \frac{FF_t}{CF_t} + b_5 \frac{FF_t}{CF_t} FIVE_{it}$$

$$(2) \quad + b_6 \frac{FF_t}{CF_t} SIX_{it} + b_7 \frac{FF_t}{CF_t} SEVEN_{it} + b_8 HD_{it} + b_9 HDSQ_{it}$$

$$+ \sum_{m=1}^{11} b_{m+9} \, MONTH_{mt} + \sum_{g=1}^{34} b_{g+20} \, GRADE_{igt}$$

$$+ b_{55} COMMPREM_{it} + b_{56} COMMDISC_{it} + e_{it}$$

where *i* is an individual lot of feeder cattle, *t* is the auction date, and *e* is an error term. Table 1 summarizes variables utilized for equation (2). To account for the feeder cattle weight-price slide, or the difference in cash price across animal weights on a per pound basis, average weight of cattle in the lot is included in the pricing model. Typically, as animal weight increases, dollar per hundredweight cash price decreases. However, we expect cash price to decrease at a decreasing rate with increasing cattle weight. To account for the nonlinear relationship between feeder price and animal weight, and to ensure a downward-sloping relationship at heavier weights, we include weight and weight squared as inverse variables. Weight variables are interacted with feeder cattle futures, allowing estimated hedge ratios to vary by cattle weight.

Corn futures are included in the pricing model because expected corn price is an economically important determinant of the weight-price relationship for feeder cattle (Dhuyvetter and Schroeder, 2000). For example, lighter-weight cattle are worth more relative to heavier cattle when corn price is lower because the associated cost of gain is low, and vice versa. Since corn price increases result in higher feed costs and lower feeder cattle cash prices (varying in magnitude by animal weight), we employ corn futures as an inverse variable and interact it with feeder futures and a categorical weight variable. This allows estimated hedge ratios to vary by corn price and the effect of corn price on the hedge ratio to be different for different animal weights. Corn price interactions are made categorical with weight to reduce collinearity and associated unstable parameter estimates resulting from interacting numerous variables with continuous weight.

Lot size and lot size squared are included to capture nonlinear price effects of the number of head sold, though these variables do not directly affect estimated hedge ratios. Similarly, categorical variables for month sold, grade, and commented cattle are included.[1] Commented cattle are those identified as having some differentiating characteristic by a USDA Agricultural Marketing Service (AMS) market reporter. We employ a separate categorical variable for comments generally associated with a premium and those associated with a discount.

[1] A separate categorical grade variable is created for every combination of feeder cattle frame size (Small, Medium, and Large) and thickness (#1 through 4), as well as mixtures of frame size and/or thickness (e.g., Small & Medium, #2-3). For example, a lot containing both medium- and large-frame cattle with a mixture of thickness scores between 1 and 2 would be graded as “Medium & Large #1-2.”

Table 1. Description of Variables Used in Conditional Hedge Ratio Hedonic Pricing Models

Characteristic	Description	Variable Name
Price ($/cwt)	Feeder cattle transaction price	*PRICE*
Feeder futures ($/cwt)	Nearby feeder cattle futures settlement price	*FF*
Weight (lb.)	Average weight per animal	*WT*
	Average weight per animal squared	*WTSQ*
Corn futures (cents/bu.)	Nearby corn futures settlement price	*CF*
Weight (0,1)	= 1 if 450 lb. ≤ average weight per animal < 550 lb.; = 0 otherwise	*FIVE*
	= 1 if 550 lb. ≤ average weight per animal < 650 lb.; = 0 otherwise	*SIX*
	= 1 if 650 lb. ≤ average weight per animal < 750 lb.; = 0 otherwise	*SEVEN*
	750 lb. ≤ average weight per animal < 850 lb. (default)	*EIGHT*
Lot size (head)	Number of head	*HD*
	Number of head squared	*HDSQ*
Month (0,1)	Month sold (January default)	*MONTH*
Grade (0,1)	Frame size and thickness (Medium & Large #1-2 default)	*GRADE*
Comments (0,1)	= 1 if commented as fancy, gaunt, thin fleshed, or value added; = 0 otherwise	*COMMPREM*
	= 1 if commented as Brahman cross, fleshy, full, or unweaned; = 0 otherwise	*COMMDISC*

Derivation of the pricing model presented in equation (2) with respect to feeder cattle futures results in equation (3), which represents the hedge ratio. With 10-year pricing models and associated parameter estimates already delineated by sex and market location, we estimate a corn-conditioned hedge ratio unique to the individual lot of feeder cattle by inserting into equation (3) the nearby corn futures settlement price and average weight per animal on the day the lot was sold.

(3)
$$\frac{dPRICE_{it}}{dFF_t} = b_1 + \frac{b_2}{WT_{it}} + \frac{b_3}{WTSQ_{it}} + \frac{b_4}{CF_t} + \frac{b_5}{CF_t}FIVE_{it} + \frac{b_6}{CF_t}SIX_{it} + \frac{b_7}{CF_t}SEVEN_{it}$$

Unconditional Hedge Ratios

Equation (4) illustrates a second hedonic pricing model, used to calculate hedge ratios that are not dependent on the price of corn and again estimated for 10-year rolling samples of transaction data by sex and market location. The unconditional hedge ratio hedonic pricing model is largely the same as the conditional. However, corn futures interaction terms are omitted to evaluate hedge ratios when they are not allowed to fluctuate with corn price. A corn futures variable is included to capture effects of corn price on feeder cattle cash prices.

(4)
$$PRICE_{it} = b_0 + b_1FF_t + b_2\frac{FF_t}{WT_{it}} + b_3\frac{FF_t}{WTSQ_{it}} + b_4CF_t + b_5HD_{it} + b_6HDSQ_{it} + \sum_{m=1}^{11} b_{m+6}\,MONTH_{mt} + \sum_{g=1}^{34} b_{g+17}\,GRADE_{igt} + b_{52}COMMPREM_{it} + b_{53}COMMDISC_{it} + e_{it}$$

The resulting hedge ratio is expressed in equation (5). Again, each lot of feeder cattle will have a unique hedge ratio that is dependent on lot-specific sex and market location hedonic pricing model coefficients from the previous 10 years and the average weight per animal on the day the lot was sold. However, the hedge ratio is not conditioned on corn price.

(5)
$$\frac{dPRICE_{it}}{dFF_t} = b_1 + \frac{b_2}{WT_{it}} + \frac{b_3}{WTSQ_{it}}$$

Hedging Risk

To evaluate cross hedging risk when using conditional versus unconditional hedge ratios, we utilize Elam's (1988) framework to calculate and compare standard deviations of the difference between net and target prices for the two methods. This study calculates hedging risk for a 90-day hedge. Net price (or actual price received) of a hedge is the cash price received plus the estimated hedge ratio multiplied by the gain (loss) on the futures position and is represented by the equation:

(6) $$N_{imt} = PRICE_{it} + b_{imt}(FF_{t-90} - FF_t)$$

where N is the net price of the hedge and b is the estimated hedge ratio. Hedging risk will vary on which method (m) is used to estimate the hedge ratio.

The target price of a hedge is the price the hedger expects to receive and is expressed as:

(7) $$T_{imt-90} = a_{imt} + b_{imt}FF_{t-90}$$

with T being the target price and a being the average generalized basis. The average generalized basis is represented by the equation:

(8) $$a_{imt} = \overline{PRICE}_{LSWY-1} - b_{imt}\overline{FF}_{Y-1}$$

where $\overline{PRICE}$ and $\overline{FF}$ are average feeder cattle cash and nearby futures prices, respectively. To calculate a, we use yearly average prices from the year prior to when the hedge is placed (Y-1). $\overline{PRICE}$ is also calculated for each combination of market location (L), sex (S), and weight class (W) to provide an expectation of cash price for an individual lot of feeder cattle that matches the lot's characteristics. Existing literature has calculated target price using the intercept estimate (b_0) from the fitted regression equation (1) as the average generalized basis. This study differs from previous studies in our calculation of the average generalized basis (and resulting target price), allowing it to represent an "expected" basis producers can estimate given previous years' price information.

The difference between net price and target price represents the uncertainty involved in the hedge (Elam and Davis, 1990) with the standard deviation (σ) of this difference being a quantitative measure of hedging risk. Equation (9) illustrates the final hedging risk formula:

$$HR_{mLSWY} = \sigma(N_{imt} - T_{imt-90}) \tag{9}$$

with *HR* being the dollar per hundredweight financial risk exposure. *HR* is calculated using both unconditional and conditional estimated hedge ratios and for every combination of market location (L), sex (S), weight class (W), and year (Y).

By utilizing transaction-level data in this framework, we can insert lot-specific hedge ratios and cash prices to calculate financial uncertainty experienced when hedging an individual lot of feeder cattle. Further, transactions data allow us to calculate hedging risk differences at a more granular level than has been available in existing literature. Previous feeder cattle hedging literature has estimated hedge ratios and compared hedging risk differences between methods for periods of 10 years or more. Our process results in yearly comparisons of hedging risk between conditional and unconditional hedge ratios, though daily hedging risk comparisons are theoretically possible given enough transactions (volume) in the cash market.

Data

Lot-level transaction data for all grades of feeder steers and heifers ranging in average weight from 450 to 849 pounds was obtained for four auction markets from January 1996 through December 2018 (U.S. Department of Agriculture Agricultural Marketing Service). Transaction data includes 158,629 lots in total. The markets chosen were Billings, MT; Joplin, MO; Salina, KS; and San Angelo, TX—all residing within the CME Feeder Cattle Index 12-State Region. These locations were chosen because they are high-volume feeder cattle markets and provide geographic dispersion. Billings and Joplin were selected to represent predominantly cow-calf regions, whereas Salina and San Angelo represent regions with significant cattle feeding. Daily settlement prices for the nearby CME Group feeder cattle and corn futures contracts were obtained for the same time period (Bloomberg L.P., 2020a). The nearby contract is defined as the nearest available contract up to contract expiration, at which point the nearby price rolls forward to the next available contract month. Descriptive statistics for select variables used in the hedonic models are reported in Table 2.

Table 2. Descriptive Statistics of Hedonic Model Variables

Dependent Variable	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
PRICE ($/cwt)	117.97	108.91	42.10	32.50	351.28
Continuous Variables	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
FF ($/cwt)	114.87	107.46	39.14	48.08	242.33
CF (cents/bu.)	358.03	347.75	151.61	174.75	831.25
WT (lb.)	626.52	621.00	106.40	450.00	849.00
HD (head)	53.41	26.00	72.95	1	1414
Categorical Variables	**% of Obs**				
FIVE (450-549 lb.)	29.05				
SIX (550-649 lb.)	30.04				
SEVEN (650-749 lb.)	24.51				
EIGHT (750-849 lb.)	16.40				
COMMPREM	5.09				
COMMDISC	4.48				
Observations = 158,629	Number of Auction Dates = 2,683				

Results

Hedonic Pricing Models

Two sets of hedonic pricing models were constructed to utilize transaction-level data in the calculation of unique hedge ratios for feeder cattle with varying lot and market characteristics. "Conditional" hedonic models from equation (2) were constructed incorporating corn and feeder cattle futures interaction terms to calculate hedge ratios conditioned on corn price. "Unconditional" hedonic models from equation (4) omitted corn and feeder cattle futures interaction terms to estimate hedge ratios independent of corn price. Both hedonic model specifications were estimated using ten years of transactions data subsequently rolling forward by dropping the oldest year as a new year of data was added, resulting in 13 total time periods considered (i.e., models were estimated for 1996-2005, 1997-2006…2008-2017).

In total, 208 hedonic models were estimated (2 model specifications x 13 time periods x 2 sexes x 4 locations). Adjusted R-squared values ranged from 0.86 (unconditional 2001-2010 Billings heifer model) to 0.98 (conditional 2006-2015 Salina heifer model). Feeder cattle futures coefficients were positive and statistically significant ($\alpha = 0.05$) for all models, as expected. We expected dollar per hundredweight price to decline at a decreasing rate as animal weight increases. This expectation held for all models based on the coefficients of the feeder cattle futures to weight ratio and the feeder futures to weight squared ratio.

For conditional models, the feeder cattle futures to corn futures ratio resulted in a positive coefficient for all but one model (1997-2006 Salina steers) and was positive and statistically significant for 96% of models. Interactions of the feeder futures-corn futures ratio with 450-549 pound, 550-649 pound, and 650-749 pound categorical weight variables yielded positive and statistically significant coefficients for 70%, 72%, and 55% of conditional models, respectively. This indicates, as anticipated, lighter-weight cattle more often had statistically significantly different feeder futures-corn futures ratio coefficients relative to the default 750-849 pounds. With corn price increases, the feeder futures-corn futures ratio decreases. As such, the feeder futures-corn futures ratio had a positive relationship with feeder cattle cash price, reflecting the tendency of cash price to move inversely to corn price (and associated cost of feed). Our expectation of a positive coefficient for the feeder futures-corn futures ratio and weight interactions generally held.

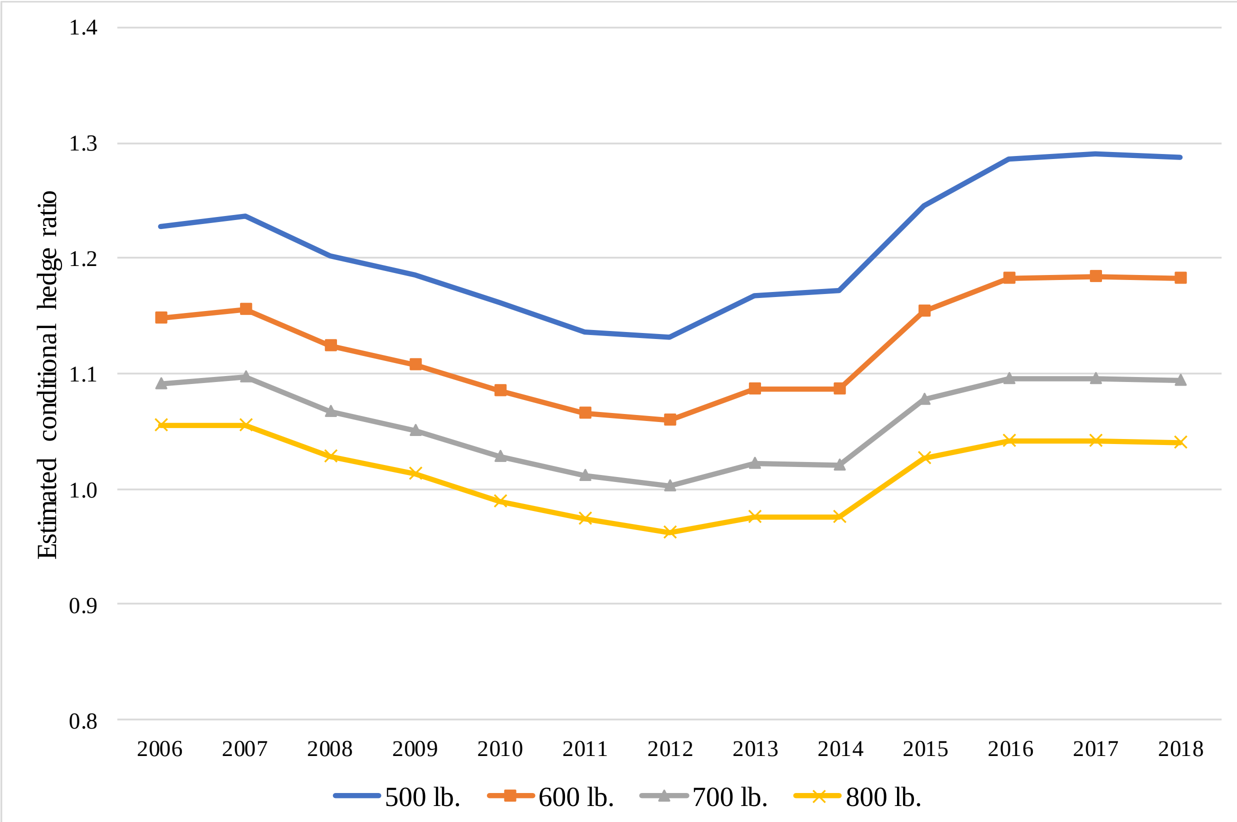
For unconditional models, corn futures had a negative coefficient for all but one model (1997-2006 San Angelo steers) and the coefficients were negative and statistically significant in 96% of models. As expected, increased corn price resulted in lower feeder cattle cash prices.

Hedge Ratios

Interaction terms of feeder futures with corn futures and animal weight in the hedonic models enabled estimating unique hedge ratios for each lot of feeder cattle. Hedge ratios for each transaction were estimated by inserting the corn futures price and average animal weight on the day the lot was sold into the conditional hedge ratio equation (3) and unconditional hedge ratio equation (5). This resulted in conditional and unconditional hedge ratios for 98,151 individual lots (each transaction from 2006 to 2018). For illustrative purposes, we used annual average nearby corn futures and four cattle weights (500, 600, 700, and 800 lb.) in equation (3) and equation (5) to estimate "example hedge ratios." Example unconditional and conditional hedge ratios for the four locations, two sex categories, four cattle weights, and 13 time periods are reported in Appendix A.

Example hedge ratios varied across weights, sex, location, and time. Hedge ratios for lighter-weight cattle typically exceeded 1.0, as their prices tend to be more variable than prices of cattle meeting futures contract specifications. Hedge ratios approached 1.0 as cattle weight increased toward feeder futures contract weight specifications, as expected. Figure 1 depicts example conditional hedge ratios for various weights of Salina feeder steers, illustrating how hedge ratios decrease as cattle weight increases. Feeder heifers generally had lower hedge ratios than steers of the same weight and market location, ranging from 0.14 lower (conditional 2018 Salina 500-pounders) to 0.04 higher (unconditional 2012 Billings 800-pounders).

Figure 1. Salina Feeder Steer Example Conditional Hedge Ratios, 2006–2018

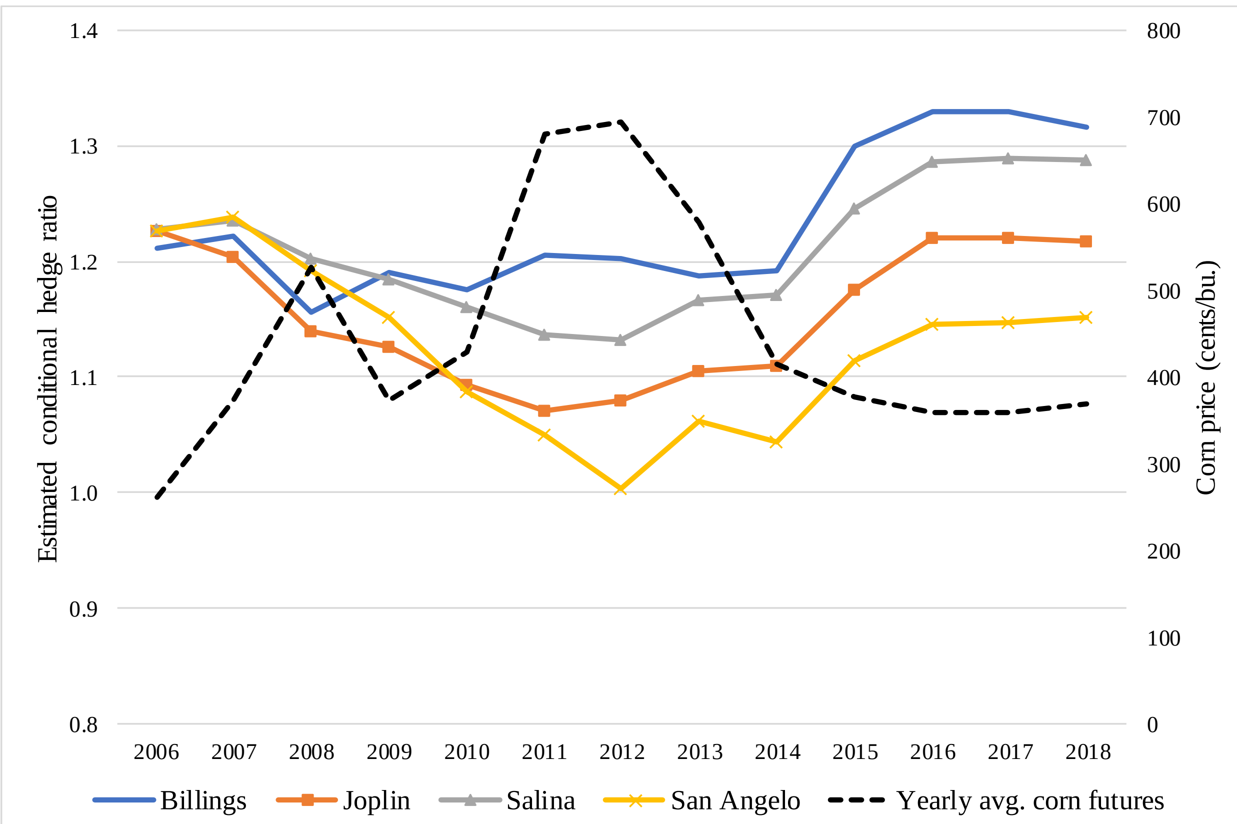


The relationship between hedge ratios and animal weight and sex is consistent with previous feeder cattle hedging literature. For instance, when analyzing hedging risk using a cash-settled contract, Schroeder and Mintert (1988) estimated Dodge City 400/500-pound feeder steer hedge ratios between 1.20 and 1.31 (depending on the contract month), compared to 700/800-pound feeder steer hedge ratios of 0.95 to 1.00. Hedge ratios for Dodge City feeder heifers ranged from 1.11 to 1.28 for 400/500-pound heifers, and from 0.87 to 0.97 for 700/800-pound heifers. Using our Salina 2018 example conditional hedge ratios for comparison, steers ranged from 1.29 for 500-pounders to 1.04 for 800-pounders, while heifers ranged from 1.15 for 500-pounders to 0.98 for 800-pounders.

Over time, example hedge ratios for all sex and weights of feeder cattle in Joplin, Salina, and San Angelo followed the same general pattern, decreasing until bottoming out in the early-

2010s and then increasing from 2014 to 2016. In contrast, corn futures prices behaved in an opposite manner, increasing to record levels around 2011-2012 before declining through the middle of the decade. Hedge ratios for Billings feeder steers of all weights were steady from 2006 into the early-2010s and exhibited an upward trend from 2014 to 2016, while hedge ratios for Billings heifers were steady for the entire time period relative to other locations and sex. Figure 2 illustrates example conditional hedge ratios for 500-pound feeder steers across the four markets along with annual average nearby corn futures.

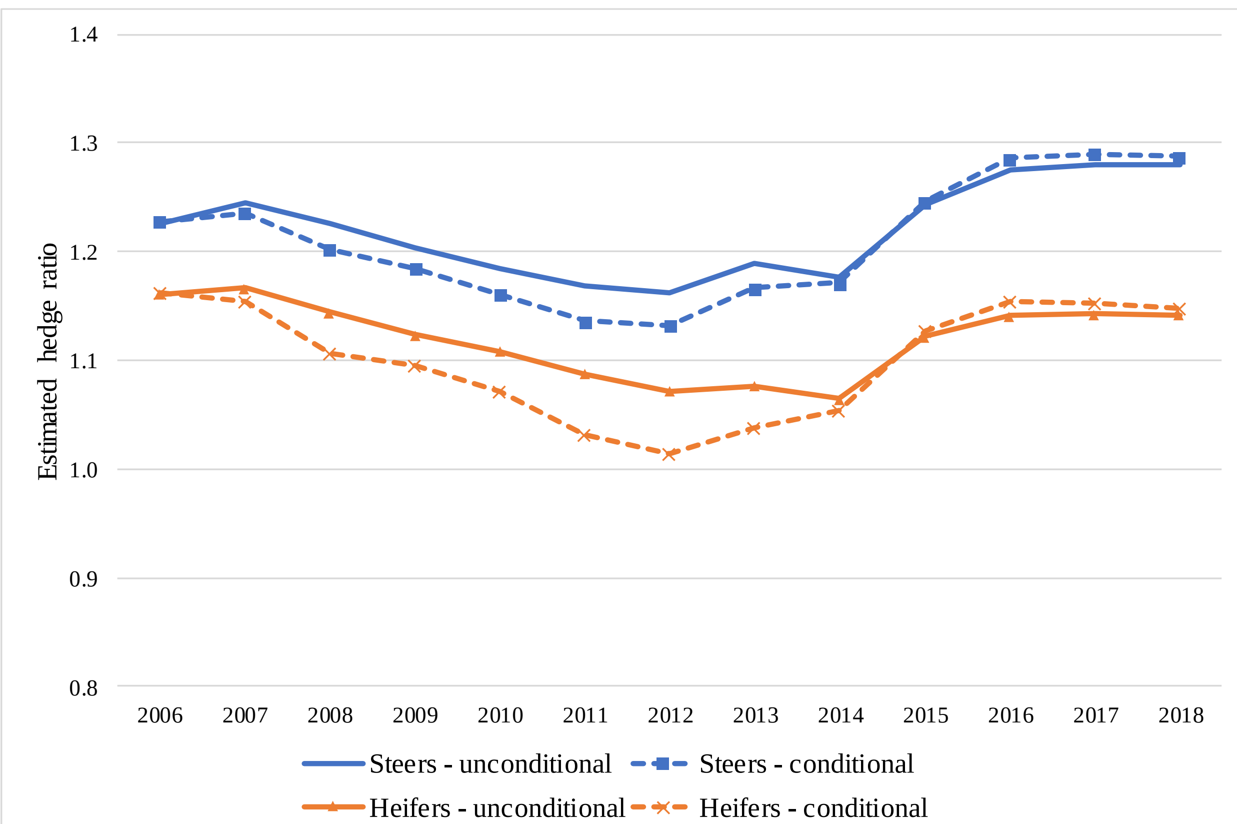
Figure 2. 500 lb. Feeder Steer Example Conditional Hedge Ratios vs. Annual Average Nearby Corn Futures, 2006–2018



Differences between unconditional and conditional hedge ratios were small, though distinct trends were present. Example hedge ratios conditioned on corn price were generally the same or slightly less than those not dependent on corn, ranging from 0.10 lower (2012 Joplin

500-pound heifers) to 0.02 higher (2007 San Angelo 500-pound steers). Example conditional hedge ratios were smaller than unconditional by the largest magnitude during the early-2010s when corn price had peaked. This pattern was consistent across all locations, sex, and cattle weights. The magnitude difference between example conditional and unconditional hedge ratios during the early-2010s was also greater for feeder heifers than steers by as much as double depending on location and weight. Example hedge ratios calculated from the two methods converged from 2014 to 2018. Figure 3 compares example unconditional and conditional hedge ratios for Salina 500-pound feeder steers and heifers, illustrating how conditional hedge ratios were generally smaller than unconditional, especially during the early-2010s, and how the difference was greater for feeder heifers.

Figure 3. Example Unconditional vs. Conditional Hedge Ratios for Salina 500 lb. Feeder Cattle, 2006–2018



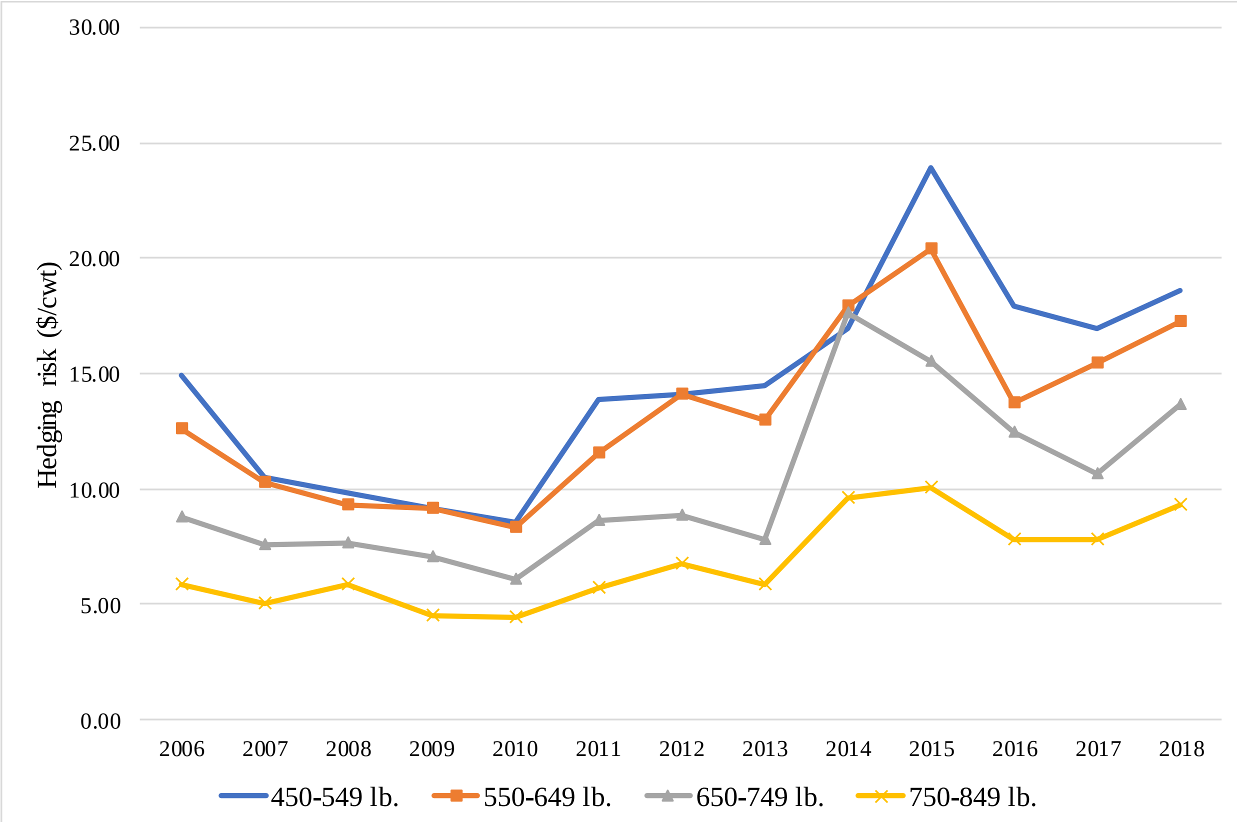
Example hedge ratios estimated using transactions data were compared to hedge ratios estimated using aggregate weekly data employed in previous literature. To do this, we calculated hedge ratios from weekly aggregate cash prices provided by the Livestock Marketing Information Center (2020) for a single market location and sex, San Angelo feeder steers (reported in Appendix Table A1). A simple regression of weekly cash price against weekly feeder cattle futures was estimated for each animal weight and 10-year period, with the regression slope coefficient being the aggregate hedge ratio for the subsequent year in an out-of-sample fashion. Aggregate hedge ratios were substantially different than hedge ratios estimated using transactions at certain times, though differences were greater for lighter-weight cattle. Aggregate hedge ratios for 500-pound feeder steers were lower than example transactions hedge ratios by as much as 0.19 in 2010 and higher than transactions hedge ratios by as much as 0.16 in 2017. This suggests hedging 500-pound steers in San Angelo using hedge ratios estimated from aggregate market data would have resulted in under-hedging by 17% in 2010 and over-hedging by 14% in 2017 relative to using hedge ratios estimated using transactions data. For the same time periods, the magnitude of difference between aggregate and example transactions hedge ratios decreased as cattle weight increased.

Hedging Risk

A measure of hedging risk was constructed to analyze and compare risk exposure using conditional and unconditional feeder cattle hedge ratios. Hedging risk was calculated as the standard deviation of the difference between net and target prices using equation (9), with net price being the actual price received from the hedge and target price being the price the hedger expected to receive. Hedging risk using conditional and unconditional hedge ratios for the four locations, two sex categories, four cattle weight categories, and 13 time periods can be viewed in Appendix B.

Hedging risk varied across weights, sex, location, and time. Hedging risk was generally greater for lighter-weight cattle and decreased as cattle weight increased for all sex and locations, with the exception of Joplin heifers, which exhibited similar hedging risk across time for 650-749 pound and 750-849 pound animals. Figure 4 depicts conditional hedging risk for Salina feeder steers and illustrates how risk differed across cattle weights. For instance, conditional hedging risk for 450-549 pound Salina steers in 2018 was $18.63 per hundredweight, compared to $9.30 for 750-849 pound steers. This suggests hedging 50,000 pounds of 450-549 pound steers (100 head) in Salina using conditional hedge ratios would result in hedging risk of $9,315, while hedging 50,000 pounds of 750-849 pound steers (~ 63 head) would result in hedging risk of $4,650.

Figure 4. Salina Feeder Steer Conditional Hedging Risk, 2006–2018



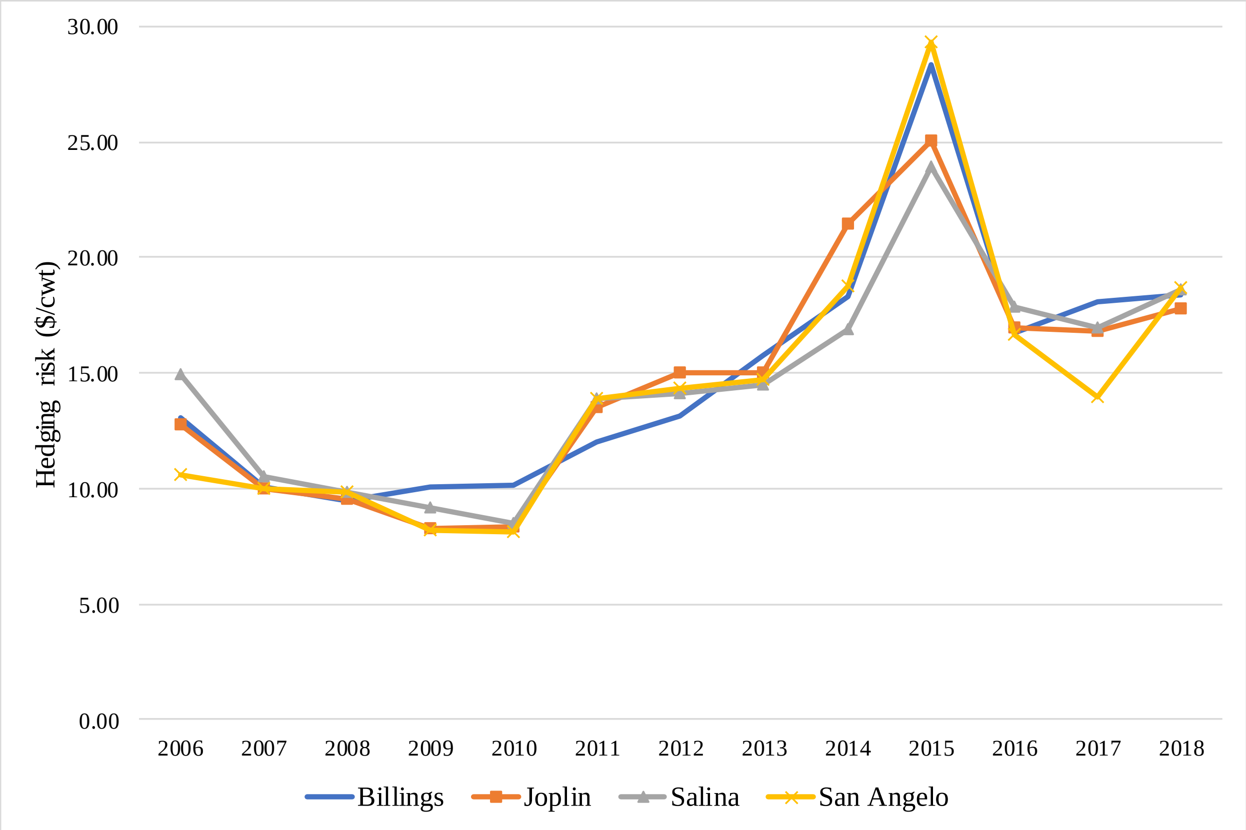
The relationship between hedging risk and animal weight is consistent with findings from past feeder cattle hedging literature. Elam and Davis (1990) found hedging risk of $3.04 ($2.66) per hundredweight for 400/500-pound Amarillo feeder steers (heifers), compared to a $1.35 ($1.51) per hundredweight hedging risk for 700/800-pound steers (heifers). Comparatively, San Angelo 2018 conditional hedging risk was $18.66 ($14.73) per hundredweight for 450-549 pound steers (heifers) and $8.88 ($9.25) per hundredweight for 750-849 pound steers (heifers). The substantial difference in conditional hedging risk estimated here and hedging risk estimated by Elam and Davis can be attributed to our use of transactions data rather than aggregated data, and differences in feeder cattle price levels and volatility between the time periods. For reference, average feeder cattle futures prices over the 1977-1988 time span (corresponding to Elam and Davis' model) were $67.28 per hundredweight with a coefficient of variation of 16%.

Average feeder futures over the 2008-2017 time span (corresponding to 2018 conditional models) were $143.70 per hundredweight with a coefficient of variation of 26%.

Elam's (1988) evaluation of hedging risk using a cash-settled contract to hedge Arkansas feeder cattle also found risk decreased as weight increased; however, he noted hedging risk was generally lower for heifers than steers of the same weight and contract month, which was surprising since the cash-settled futures contract reflected steer prices. We likewise found hedging risk for feeder heifers was generally lower than that of steers of the same weight and location, ranging from $9.35 per hundredweight lower (unconditional 2014 Salina 650-749 pounders) to $2.57 per hundredweight higher (conditional 2015 Billings 750-849 pounders).

Across time, feeder cattle hedging risk for all sex, weights, and locations followed the same general pattern, increasing from the late-2000s before peaking in 2015. Hedging risk tended to decline post-2015 and remained at levels similar to, or slightly above, those of 2011-2013. Figure 5 depicts conditional hedging risk for 450-549 pound feeder steers across all locations. While experiencing the same reduction following 2015, hedging risk for Billings, Joplin, and Salina steers remained at relatively high levels from 2016 to 2018. Hedging risk peaked one year earlier (2014) than the general trend for both Salina 650-749 pound steers and Joplin 750-849 pound heifers. Rapid increases in hedging risk in 2014-2015 across all sex and locations coincides with historically high feeder cattle prices and volatility during that time period.

Figure 5. 450-549 lb. Feeder Steer Conditional Hedging Risk, 2006–2018



The difference in hedging risk using conditional versus unconditional hedge ratios was small, ranging from a 2.95% reduction in risk (2013 San Angelo 750-849 pound heifers) to a 1.94% increase in risk (2016 San Angelo 450-549 pound heifers) by using conditional hedge ratios compared to unconditional. To further evaluate and summarize hedging risk with conditional and unconditional hedge ratios, we estimated a model regressing hedging risk against selected variables:

$$HR_{mLSWY} = b_0 + b_1FIVE + b_2SIX + b_3SEVEN + b_4(FIVE \text{ x } COND) + b_5(SIX \text{ x } COND) + b_6(SEVEN \text{ x } COND) + b_7SALINA + b_8JOPLIN + b_9BILLINGS + b_{10}HEIFER + \sum_{y=1}^{12} b_{y+10}\, YEAR_y + e_{mLSWY} \quad (10)$$

Categorical variables were included in the model for 450-549 pound (*FIVE*), 550-649 pound (*SIX*), and 650-749 pound (*SEVEN*) weight groupings, market location (*SALINA*, *JOPLIN*, and *BILLINGS*), sex (*HEIFER*), and year (*YEAR*). A categorical variable denoting whether risk was calculated using conditional hedge ratios (*COND*) was interacted with categorical weight variables to determine effects of corn-conditioned hedging across weight. A second, similar model was estimated omitting year variables. Results of the models (reported in Table 3) confirm our findings that hedging risk decreased as feeder cattle weight approached contract weight specifications and hedging heifers involved lower financial risk than hedging steers. Hedging risk was $6.69, $4.22, and $1.69 per hundredweight higher for 450-549, 550-649, and 650-749 pound animals compared to the default 750-849 pound, respectively. Each cattle weight variable was statistically significant ($\alpha = 0.05$). Hedging feeder heifers resulted in a $1.95 per hundredweight lower hedging risk compared to hedging steers on average and was also statistically significant. Hedging risk was $5.69 per hundredweight lower in 2009 compared to 2018 (default) and $5.07 per hundredweight higher in 2015, which reflects the historically high cattle prices and volatility that occurred in late-2014 and 2015. All year variables were statistically significant. Conditional hedge ratios resulted in small ($0.019 to $0.033 per hundredweight) and statistically insignificant reductions in hedging risk for each weight category compared to unconditional hedge ratios.

Table 3. Summary of Regression Analysis for Variables Predicting Hedging Risk

	Default = 749-849 lb., unconditional hedge ratio, San Angelo, steer, 2018	
	Hedging risk ($/cwt)	
	Categorical year	No categorical year
Intercept	10.031***	7.797***
	(0.260)	(0.334)
FIVE	6.689***	6.689***
	(0.201)	(0.409)
SIX	4.219***	4.219***
	(0.201)	(0.409)
SEVEN	1.685***	1.685***
	(0.201)	(0.409)
FIVE x COND	-0.033	-0.033
	(0.232)	(0.472)
SIX x COND	-0.029	-0.029
	(0.232)	(0.472)
SEVEN x COND	-0.019	-0.019
	(0.232)	(0.472)
SALINA	-0.527***	-0.527
	(0.164)	(0.334)
JOPLIN	-0.826***	-0.826**
	(0.164)	(0.334)
BILLINGS	-0.207	-0.207
	(0.164)	(0.334)
HEIFER	-1.949***	-1.949***
	(0.116)	(0.236)
2006	-3.705***	
	(0.296)	
2007	-5.234***	
	(0.296)	
2008	-5.208***	
	(0.296)	
2009	-5.685***	
	(0.296)	
2010	-5.496***	
	(0.296)	
2011	-2.591***	
	(0.296)	
2012	-2.052***	
	(0.296)	

Table 3. Summary of Regression Analysis for Variables Predicting Hedging Risk continued

2013	-2.425***	
	(0.296)	
2014	0.993***	
	(0.296)	
2015	5.068***	
	(0.296)	
2016	-1.400***	
	(0.296)	
2017	-1.315***	
	(0.296)	
Observations	832	832
R^2	0.855	0.395
Adjusted R^2	0.851	0.387
Residual Std. Error	1.676 (df = 809)	3.403 (df = 821)
F Statistic	217.302*** (df = 22; 809)	53.546*** (df = 10; 821)
Note:	Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level. Values in parenthesis are standard errors of estimated coefficients.	

Conclusions

Corn price is an important determinant of feeder cattle weight-price slides. Changes in corn price affect weight-price slides and, consequently, feeder cattle hedge ratios. We implemented transactions data to quantify hedge ratios conditioned on corn price and evaluated hedging risk experienced when using corn-conditioned hedge ratios compared to hedge ratios not dependent on corn price. Conditional and unconditional hedge ratios were greater than 1.0 for lighter-weight cattle and approached 1.0 as cattle weight increased toward feeder futures contract weight specifications. Hedging lighter-weight cattle requires a larger futures position to offset variability of cash prices, relative to cattle meeting contract weight specifications. Hedging feeder heifers generally requires a smaller futures position than hedging steers of the same weight.

Hedge ratios for Joplin, Salina, and San Angelo steers and heifers exhibited the same general pattern over time, declining until bottoming out in the early-2010s and then increasing from 2014 to 2016. Hedge ratios were smallest in these locations when corn was experiencing record high price levels. Hedge ratios for Billings steers and heifers were steady over time, though steer hedge ratios exhibited an upward trend from 2014 to 2016, suggesting the impact of corn price on feeder cattle hedge ratios varies across markets.

Conditional hedge ratios were generally smaller than unconditional, and by the greatest magnitude during the early-2010s when corn price had reached its peak. The size of the futures position taken can vary substantially on the method used to calculate hedge ratios, corn price at the time the hedge is placed, and the weight and sex of cattle being hedged. For instance, hedging 500-pound Joplin feeder steers in 2012 using an unconditional hedge ratio (1.15) resulted in over-hedging by 6.5% compared to using a conditional hedge ratio (1.08). Hedging 800-pound Joplin heifers the same year using an unconditional hedge ratio (0.95) resulted in over-hedging by 8.0% compared to using a conditional hedge ratio (0.88). Hedgers need to consider cattle characteristics, market conditions, and hedge ratio calculation methods when implementing a hedging strategy to minimize over- or under-hedging and reduce associated transaction costs.

Estimates were made for hedging risk experienced when using conditional and unconditional hedge ratios. Hedging risk was greater for lighter-weight cattle and decreased as cattle weight increased toward feeder futures contract weight specifications, with heifers generally having lower hedging risk than steers of the same weight and location. Hedging risk for all locations, sex, and weight tended to increase from the late-2000s, peak in 2015, and then decline to levels similar to, or slightly above, those experienced in 2011-2013. Billings, Joplin, and Salina steer hedging risk declined post-2015 but remained high relative to 2011-2013 levels; by as much as $3-4 per hundredweight depending on the location and weight. Declines in hedging risk post-2015 suggests the feeder cattle market and hedging effectiveness partially returned from record high volatility experienced in 2014-2015 but was not consistent across market locations and sex.

Hedging risk reductions achieved by using conditional hedge ratios compared to unconditional were small and statistically insignificant for all cattle weights. While corn price fluctuations affect feeder weight-price slides and associated hedge ratios, hedge ratios conditioned on corn price do not significantly improve the ability to mitigate feeder cattle hedging risk. Regardless of the method used to calculate feeder cattle hedge ratios, hedge ratios and hedging risk varied substantially across time, location, sex, and weight. This implies generalized hedge ratios—those calculated for large geographic areas, broad classifications of feeder cattle, or over extended periods of time (such as those in previous hedging literature)—may not accurately portray the relationship between cash price of heterogeneous feeder cattle and futures prices. More granular data and frequent calculation could provide hedge ratios that more effectively manage financial risk of hedging feeder cattle with differing characteristics and market conditions.

Article 2 – Feeder Cattle Basis Risk and Determinants

Introduction

In the presence of notable market uncertainty, the CME Group Feeder Cattle Futures contract facilitates risk transfer from commercial users (hedgers) managing price risk to speculators seeking to profit from market volatility. The risk-transfer function is a necessary component of any futures contract, and the performance and use of a contract determines its viability as a risk management tool. Dramatic price swings in U.S. cattle markets during 2014–2016 prompted concerns over the effectiveness of cattle futures contracts as hedging instruments (National Cattlemen's Beef Association, 2016). As a thinly traded contract relative to live cattle futures (Bina and Schroeder, 2019), concerns were exacerbated for feeder futures. Peel (2020) argued "Feeder futures have become increasingly volatile in ways that often appear unrelated to market fundamentals. Erratic futures price movements and increased basis volatility makes it difficult or impossible for the industry to use feeder futures for its two primary roles of risk management and price discovery." Undue basis variability would impair the risk-transfer function of the feeder cattle futures contract. This study was motivated to assess these concerns and evaluate how feeder cattle hedging performance has evolved.

The purpose of this study is to determine whether feeder cattle basis risk has changed over time and identify factors driving basis risk. In particular, we utilize hedonic modeling of transaction-level data from a comprehensive set of 32 weekly feeder cattle auction markets. The models include feeder cattle futures prices as dependent variables and we use these models to predict feeder cattle transaction prices out of sample. Given the way our model is specified; out-of-sample transaction price prediction errors represent unexplained cash price deviations from feeder cattle futures prices or other random variation. This prediction error serves as a direct measure of basis risk. We then estimate impacts of market conditions and cattle characteristics on out-of-sample transaction price prediction errors to determine how basis risk has changed over time and varied with market fundamentals.

Previous basis forecasting and basis risk assessment literature has focused primarily on live cattle futures and has utilized aggregate price data (e.g., Leuthold, 1979; Garcia, Leuthold, and Sarhan, 1984; Liu et al., 1994; Parcell, Schroeder, and Dhuyvetter, 2000; Coffey, Tonsor, and Schroeder, 2018). Our study differs in that we implement transactions data in transaction price predictions and use out-of-sample errors as a measure of feeder cattle basis risk. For heterogeneous feeder cattle, transaction price and associated basis varies on lot characteristics as well as market conditions at the time of sale. Aggregate basis forecasts and risk assessments cannot be expected to accurately portray cash-futures relationships for individual transactions possessing varying product traits. As such, implementing transactions data allows for a more granular assessment of basis risk across individual transaction and fundamental market characteristics than the aggregate data employed in previous literature. Since basis variation impacts the effectiveness of feeder futures to transfer price risk, understanding how and why basis risk is changing over time is essential for hedgers making decisions on whether to use the contract as well as for contract-design purposes. Results indicate feeder cattle market volatility had statistically and economically significant impacts on feeder cattle basis risk. We further find basis risk varied across geographic location as well as seasonally. Overall basis risk increased dramatically in 2014–2016 relative to historical norms, but returned to levels similar to 2011 by 2018.

Previous Studies

Futures contract success depends on predictability of basis, defined as cash price minus futures price. Unexpected basis variation reduces the ability of a futures contract to transfer risk, decreases access to alternative forward pricing mechanisms, and reduces overall use of the futures contract (Garcia and Sanders, 1996). Adverse unexpected basis changes result in financial losses, relative to expectations, to hedgers. Given the importance of basis on hedging effectiveness, previous literature has forecasted basis and analyzed basis determinants in a variety of ways.

Leuthold (1979) hypothesized live cattle basis reflected the expected change in cash price over time, caused by supply shifts. To test this, he regressed monthly live cattle basis against cattle supply factors approaching contract maturity. A large portion of basis variation for contracts two to seven months from maturity could be explained by cattle supply factors including: cattle slaughter, cattle on feed, corn price, feeder and fed steer prices, and seasonal variables. Tomek (1980) noted on Leuthold's work that live cattle futures prices for contracts four to seven months from maturity had no relationship with current fed steer cash prices, but the relationship moved toward one-for-one as contract maturity approached. This suggests live cattle spot and futures prices move independently for more distant futures contracts, but the two market prices move approximately one-to-one as futures maturity nears. Livestock is a non-storable commodity that changes form over time. Thus, a disconnect between current cash prices and deferred contracts can be expected (Koontz, Hudson, and Hughes, 1992), though nearby basis should become more predictable as animals mature toward contract specifications.

Garcia, Leuthold, and Sarhan (1984) posited that basis for a non-storable commodity is the difference between current cash price and expected future cash price and is a function of expected shifts in supply and demand. Using daily aggregate prices from several Midwest markets, they modeled live cattle and live hog basis variability as a function of the consumer price index, location, and time to maturity, among other factors. Basis risk was related to long-term price patterns and unexpected changes in price. Using monthly aggregate Kansas, Colorado, and Texas data to determine factors affecting live cattle basis, Parcell, Schroeder, and Dhuyvetter (2000) found corn price, market fundamentals, and seasonality were important basis determinants. Liu et al. (1994) focused on concerns of lack of convergence between cash and futures prices, employing monthly average price data to forecast live cattle basis during the month preceding contract delivery. Futures market variables such as open interest and the lagged spread between nearby and a 2-month deferred contract were statistically significant in explaining variation in live cattle basis, suggesting futures market information should be considered with supply and demand factors when forecasting nearby basis.

Following the feeder cattle futures contract change from physical delivery to cash settlement in 1986, Kenyon, Bainbridge, and Ernst (1991) analyzed the effect of cash settlement on basis variability and predictability. Implementing weekly average price data for Oklahoma City and Southwest Virginia markets, standard deviations of feeder steer basis declined 3%-14% after cash settlement was introduced, but results were not statistically significant. Further, transaction data for 16 Virginia markets was used to estimate basis as a function of lot characteristics and futures contract month and to forecast basis before and after implementation of cash settlement. In general, basis forecast errors for individual lots did not change under cash settlement, suggesting basis risk did not change for feeder cattle hedgers under the new contract specifications.

Assessing feeder cattle basis levels across key production states, Seamon, Sullivan, and Umubyeyi (2019) found statistically significant differences in basis across Nebraska, Kansas, and Texas. Kansas and Texas, but not Nebraska, exhibited statistically significant seasonality in feeder cattle basis. Though seasonal patterns in feeder cattle basis can be accounted for in some markets, unexpected basis fluctuations reduce hedging performance. An analysis of market fundamentals and price momentum on live cattle hedging by Coffey, Tonsor, and Schroeder (2018) found the impacts of market factors (such as aggregate supply of cattle, cattle market weights, and delivery costs) and price trends on basis prediction errors varied across regions. For example, Kansas and Texas exhibited weaker than expected basis when heavier than average cattle were being marketed. However, the results were not consistent across cattle feeding regions. The diversity of cattle markets and basis predictability across regions highlighted the need for cattle producers to understand local market conditions. Doing so necessitates detailed basis risk assessments, addressed in this study.

Procedure

A multi-step procedure was used to assess basis risk. First, hedonic models were estimated using five years of transaction data (and rolled forward yearly) to predict individual transaction prices for the subsequent year in an out-of-sample fashion. Second, out-of-sample prediction errors, which are directly interpreted as out-of-sample basis values for individual transactions, were calculated for all transactions across each out-of-sample year. Third, out-of-sample mean absolute values of prediction errors were used to quantify basis variation.[2] Fourth, out-of-sample basis variation was regressed against market conditions to quantify factors associated with basis risk.

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[2] Risk is not evaluated from a short or long hedging perspective, which necessitates a directional measure of basis risk. This study focuses on overall risk of using the feeder futures contract and, as such, employs mean absolute errors as the measure of basis variation.

Hedonic Models

Hedonic pricing models were estimated separately by sex and market location for 5-year rolling samples of transaction data. Using the coefficients from these models, out-of-sample feeder cattle transaction price predictions were made for the subsequent year. Thus, each lot had an out-of-sample predicted price dependent on 1) lot-specific sex and market location hedonic pricing model coefficients from the previous five years and 2) lot characteristics and market conditions on the day the lot was sold.

The hedonic pricing model employed is:

$$\begin{aligned} PRICE_{it} = {} & b_0 + b_1 FF_t + b_2 \frac{FF_t}{WT_{it}} + b_3 \frac{FF_t}{WTSQ_{it}} + b_4 \frac{FF_t}{CF_t} + b_5 \frac{FF_t}{CF_t} FIVE_{it} \\ & + b_6 \frac{FF_t}{CF_t} SIX_{it} + b_7 \frac{FF_t}{CF_t} SEVEN_{it} + b_8 HD_{it} + b_9 HDSQ_{it} \\ & + \sum_{m=1}^{11} b_{m+9}\, MONTH_{mt} + \sum_{g=1}^{34} b_{g+20}\, GRADE_{igt} + b_{55} COMMPREM_{it} \\ & + b_{56} COMMDISC_{it} + e_{it} \end{aligned} \tag{11}$$

where *i* is an individual lot of feeder cattle, *t* is the auction date, and *e* is an error term. Table 4 summarizes variables used in equation (11). Nearby feeder cattle futures prices are included to account for the effect of futures price on cash price, making the error term reflect basis risk (random error). The nearby futures price is defined here as the settlement price of the nearby contract up to contract expiration, at which point the nearby price rolls forward to the next contract month.

Average weight of cattle in the lot is included to account for changing cash price per pound across animal weight. Price is expected to decrease at a decreasing rate as animal weight increases. Weight and weight-squared are made inverse variables to account for the nonlinear relationship between feeder cattle price and animal weight, and to guarantee a downward-sloping relationship at heavier weights. In addition, feeder futures price impact on cash price is conditional on animal weight (i.e., lighter-weight cattle prices vary more with futures prices compared to price of cattle meeting futures contract weight specifications). As such, weight and weight-squared variables are interacted with feeder futures.

Nearby corn futures prices are expected to influence the feeder cattle weight-price slide (Dhuyvetter and Schroeder, 2000). When corn price (and associated cost of gain) decreases, cash price of lighter-weight cattle increases, making lighter cattle more valuable on a dollar per pound basis than heavier cattle. Further, corn price may influence how feeder cattle futures prices affect cash prices and this influence could vary by animal weight. For instance, when corn price is high, price of lighter-weight cattle will be more responsive to changes in feeder cattle futures prices compared to cattle meeting futures contract weight specifications. To account for the influence of corn price on cash feeder price and the futures-cash relationship, corn is included as an inverse variable and is interacted with feeder futures and categorical weight. Interacting numerous variables with continuous cattle weight variables resulted in collinearity and unstable parameter estimates, necessitating interactions of corn price with categorical, rather than continuous, weight variables.

Nonlinear transaction price effects of the number of head sold are captured by including lot size and lot size squared. Categorical variables for month sold, grade, and commented cattle capture price effects of lot-specific characteristics.[3] Cattle identified by a USDA AMS market reporter as having a differentiating characteristic are "commented" in market reports. Since comments are generally associated with a price premium or discount, separate categorical variables were created for comments typically associated with a premium and comments typically associated with a discount.

[3] Categorical grade variables are created for all combinations of feeder cattle frame size (Small, Medium, and Large) and thickness (#1 through 4), and for mixtures of frame size and/or thickness (e.g., Medium & Large, #2-3, etc.). For example, a lot containing both medium- and large-frame cattle with a mixture of thickness scores between 1 and 2 would have a categorical grade of "Medium & Large #1-2." The occurrence of each grade variable varies across hedonic models.

Table 4. Description of Variables Used in Hedonic Pricing Models

Characteristic	Description	Variable Name
Price ($/cwt)	Feeder cattle transaction price	*PRICE*
Feeder futures ($/cwt)	Nearby feeder cattle futures settlement price	*FF*
Weight (lb.)	Average weight per animal	*WT*
	Average weight per animal squared	*WTSQ*
Corn futures (cents/bu.)	Nearby corn futures settlement price	*CF*
Weight (0,1)	= 1 if 450 lb. ≤ average weight per animal < 550 lb.; = 0 otherwise	*FIVE*
	= 1 if 550 lb. ≤ average weight per animal < 650 lb.; = 0 otherwise	*SIX*
	= 1 if 650 lb. ≤ average weight per animal < 750 lb.; = 0 otherwise	*SEVEN*
	750 lb. ≤ average weight per animal < 850 lb. (default)	*EIGHT*
Lot size (head)	Number of head	*HD*
	Number of head squared	*HDSQ*
Month (0,1)	Month sold (January default)	*MONTH*
Grade (0,1)	Frame size and thickness (Medium & Large #1-2 default)	*GRADE*
Comments (0,1)	= 1 if commented as fancy, gaunt, thin fleshed, or value added; = 0 otherwise	*COMMPREM*
	= 1 if commented as Brahman cross, fleshy, full, or unweaned; = 0 otherwise	*COMMDISC*

Out-of-sample prediction errors from the hedonic models are the difference in feeder cattle transaction price and predicted price. Because we include feeder cattle futures prices on the right-hand side of the models, prediction errors are variation in transaction price unexplained by feeder cattle futures and other model variables. This unexplained variation in feeder cattle cash price provides a measure of basis risk. This is similar to studies that have used historical average basis values to predict basis out-of-sample using aggregate market data (e.g., Tonsor, Dhuyvetter, and Mintert, 2004; Coffey, Tonsor, and Schroeder, 2018). However, since we use transaction prices, we are able to measure basis for each transaction across numerous cofactors including animal sex, weight, season, year, market location, etc., providing a much more detailed basis assessment than previous studies.

Mean Absolute Errors

Out-of-sample price predictions derived from the hedonic pricing models are used to compute mean absolute errors (MAE), or basis variation, expressed as:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|PRICE_{it} - PREDICTION_{it}| \quad (12)$$

where *n* is the number of lots sold at each market location (*l*), for each sex (*s*), during each month (*m*), for each weight class (*w*). For notational convenience, subscripts for location, sex, month, and weight class are omitted in equation (12). *PREDICTION* is each lot's unique out-of-sample predicted transaction price and the term inside the absolute value bracket is the difference of each predicted price from the actual transaction price. MAE is calculated separately by location (*l*), sex (*s*), month (*m*), and weight class (*w*).

Explaining MAE

To evaluate how basis risk has changed over time and determine factors associated with those changes, we regress MAE values calculated from equation (12) against selected variables. The model is:

$$\begin{aligned} MAE_{lsmw} = {} & b_0 + b_1 AVGFF_m + b_2 AVGCF_m + b_3 AVGFIV_m + b_4 AVGCIV_m \\ & + \sum_{l=1}^{31} b_{4+l}\, LOCATION_l + \sum_{y=1}^{21} b_{35+y}\, YEAR_y + \sum_{m=1}^{11} b_{56+m} MONTH_m \\ & + b_{68} FIVE_w + b_{69} SIX_w + b_{70} SEVEN_w + e_{lsmw} \end{aligned} \quad (13)$$

Table 5 summarizes variables utilized for equation (13). Monthly average feeder cattle and corn futures prices are included to determine how changes in market prices impact feeder cattle basis risk (out-of-sample mean absolute errors). Monthly average nearby feeder cattle and corn implied volatilities are included to evaluate effects of market volatility on basis risk.[4] Implied volatility of an option contract is the market's forecast of future volatility in the underlying asset price (Canina and Figlewski, 1993). In this instance, implied volatility is the market's expectation of future volatility in feeder cattle and corn futures priced into option premiums. Categorical variables are included for market location to determine how basis risk varies across geographic locations. Categorical year variables evaluate how feeder cattle basis risk has changed over time, while categorical months allow for seasonality in basis risk. Lastly, categorical weight variables are included to measure basis risk across animal weight.

[4] Bloomberg calculates nearby implied volatility as the weighted average of the volatilities of the two call (put) options closest to the at-the-money strike price, and for the nearest contract expiration that is at least 20 days out.

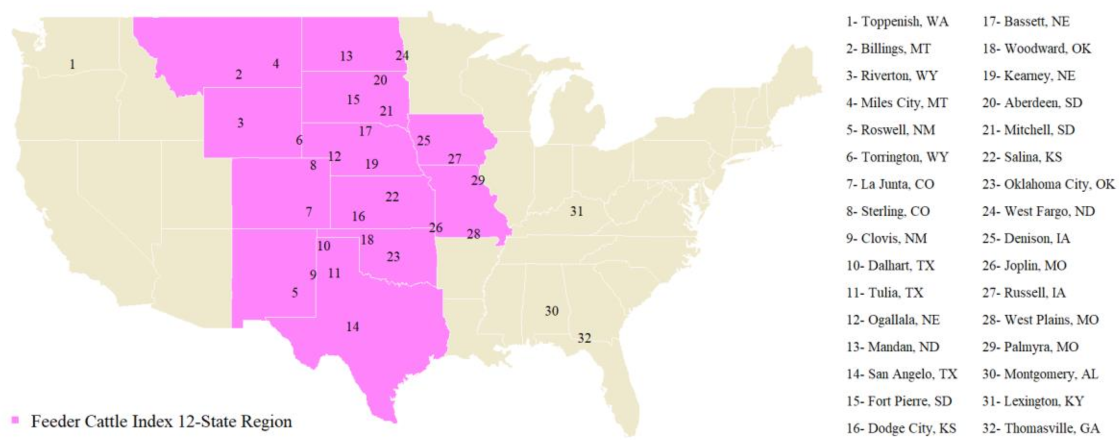
Table 5. Description of Variables Used in MAE Models

Characteristic	Description	Variable Name
Mean absolute error ($/cwt)	Mean absolute error of predicted feeder cattle transaction prices	*MAE*
Feeder futures ($/cwt)	Monthly average nearby feeder cattle futures settlement prices	*AVGFF*
Corn futures (cents/bu.)	Monthly average nearby corn futures settlement prices	*AVGCF*
Feeder cattle implied volatility (annualized %)	Monthly average nearby implied volatility of at-the-money feeder cattle options (average of call and put IVs)	*AVGFIV*
Corn implied volatility (annualized %)	Monthly average nearby implied volatility of at-the-money corn options (average of call and put IVs)	*AVGCIV*
Market location (0,1)	Market location of transactions (Oklahoma City default)	*LOCATION*
Year (0,1)	Year of transactions (2018 default)	*YEAR*
Month (0,1)	Month of transactions (January default)	*MONTH*
Weight (0,1)	Transactions of 450 lb. ≤ average weight per animal < 550 lb.	*FIVE*
	Transactions of 550 lb. ≤ average weight per animal < 650 lb.	*SIX*
	Transactions of 650 lb. ≤ average weight per animal < 750 lb.	*SEVEN*
	Transactions of 750 lb. ≤ average weight per animal < 850 lb. (default)	*EIGHT*

Data

Transactions data for all grades of feeder steers and heifers ranging in average weight from 450 to 849 pounds were obtained from USDA AMS for 32 auction market locations (U.S. Department of Agriculture Agricultural Marketing Service). Figure 6 depicts the selected market locations. Transaction data goes through 2018; however, the earliest available data varies by market (summarized in Table 6). Twenty-eight markets reside within the CME Feeder Cattle Index 12-State Region and were chosen as they are high-volume feeder cattle markets and provide geographic dispersion. Toppenish, WA (Pacific Northwest), and Montgomery, AL, Lexington, KY, and Thomasville, GA (Southeast) were selected to evaluate basis risk in higher-volume markets outside of the 12-State Region. To reduce impacts of data collection errors and abnormal transactions, lots of less than 5 or more than 1,000 head were omitted. Likewise, lots where transaction price was less than 50% or greater than 180% of the same day's nearby feeder futures settlement price were omitted.[5] Data cleaning eliminated 78,040 observations, leaving 745,146 lots for analysis.

Figure 6. Selected Feeder Cattle Market Locations Used to Evaluate Basis Risk



[5] Asymmetric cutoffs are due to the data set including no cattle that exceed futures contract weight specifications (700-899 pounds) but a portion of cattle with weight well below contract specifications (e.g., 450 pounds). As such, we expect cattle on the lighter end of the data set to have cash prices that differ from futures prices more than cash prices of cattle on the heavier end.

Table 6. Summary of Selected Feeder Cattle Markets Analyzed

Market	First Year of Data	Observations	Number of Auction Dates
[Montgomery, AL]	2005	4,264	523
LaJunta, CO	1994	16,404	931
Sterling, CO	2003	8,873	360
[Thomasville, GA]	2003	3,652	552
Denison, IA	1998	13,408	562
Russell, IA	1995	13,112	504
Dodge City, KS	1995	36,770	1,199
Salina, KS	1995	40,088	1,156
[Lexington, KY]	2009	9,076	621
Joplin, MO	1996	59,396	1,201
Palmyra, MO	1996	16,049	967
West Plains, MO	1996	55,248	1,102
Billings, MT	1994	17,017	1,232
Miles City, MT	2008	6,769	389
Mandan, ND	1998	14,071	610
West Fargo, ND	1995	13,210	477
Bassett, NE	1999	9,795	469
Kearney, NE	1994	23,059	965
Ogallala, NE	1999	10,196	491
Clovis, NM	1995	29,718	1,082
Roswell, NM	1995	18,974	1,051
Oklahoma City, OK	1994	78,739	1,219
Woodward, OK	1994	40,079	1,211
Aberdeen, SD	2003	17,507	747
Fort Pierre, SD	1996	17,393	799
Mitchell, SD	1997	19,212	713
Dalhart, TX	1992	35,370	1,272
San Angelo, TX	1994	36,391	1,291
Tulia, TX	2001	27,401	859
[Toppenish, WA]	1995	19,891	1,183
Riverton, WY	1995	12,065	957
Torrington, WY	1995	21,949	1,496

[ ] Denotes a market outside of Feeder Cattle Index 12-State Region

Daily settlement prices for the nearby CME Group feeder cattle and corn futures contracts were obtained (Bloomberg L.P., 2020a). The nearby futures price was defined as the settlement price of the nearest available contract up to contract expiration, at which point the nearby price rolled forward to the next available contract month. Daily put and call implied volatilities (IV) for nearby at-the-money feeder cattle and corn options were likewise obtained (Bloomberg L.P., 2020b). An average of the call and put IV was calculated to obtain a single daily IV value. If a call (put) IV was missing, the put (call) IV was used as the daily IV value. Monthly average implied volatilities were calculated from the daily values for both feeder cattle and corn. Descriptive statistics for select variables used in equations (11) and (13) are reported in Tables 7 and 8, respectively.

Table 7. Descriptive Statistics of Hedonic Model Variables

Dependent Variable	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
PRICE ($/cwt) - Steers	123.00	112.61	44.62	30.00	363.76
PRICE ($/cwt) - Heifers	113.31	104.81	40.29	31.00	372.00
Continuous Variables	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
FF ($/cwt)	109.44	99.33	38.54	48.08	242.33
CF (cents/bu.)	342.17	303.75	145.59	174.75	831.25
WT (lb.)	630.98	624.00	107.81	450.00	849.00
HD (head)	64.54	30.00	92.87	5	1000
Categorical Variables	**% of Obs**				
FIVE (450-549 lb.)	27.99				
SIX (550-649 lb.)	29.28				
SEVEN (650-749 lb.)	24.98				
EIGHT (750-849 lb.)	17.75				
COMMPREM	6.01				
COMMDISC	5.85				
Observations (Steers) = 389,326		Number of Auction Dates = 6,331			
Observations (Heifers) = 355,820					

Table 8. Descriptive Statistics of MAE Model Variables

Dependent Variable	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
MAE ($/cwt) - Steers	17.95	13.95	13.82	0.007	136.55
MAE ($/cwt) - Heifers	15.17	11.40	12.49	0.011	109.36
Continuous Variables	**Mean**	**Median**	**SD**	**Minimum**	**Maximum**
AVGFF ($/cwt)	117.24	109.08	38.17	67.80	239.52
AVGCF (cents/bu.)	357.03	348.55	153.50	178.29	803.54
AVGFIV (annualized %)	11.35	10.91	3.89	3.83	24.61
AVGCIV (annualized %)	26.62	24.88	7.83	11.31	48.61
Observations (Steers) = 23,237					
Observations (Heifers) = 23,089					

Results

Hedonic Pricing Models

Hedonic pricing models were estimated to utilize transaction-level data in predicting transaction price for feeder cattle with varying lot characteristics and market conditions at time of sale. The hedonic framework depicted in equation (11) was applied to each market location and sex, and for five years of transactions data subsequently rolling forward by adding a new year of data and dropping the oldest year. The number of hedonic pricing models estimated for each market location depended on data availability. For example, the first year of available data for Salina, KS was 1995. Hedonic models for Salina steers and heifers were estimated for time periods of 1995–1999, 1996–2000…2013–2017. A total of 1,060 hedonic models were estimated. Adjusted R-squared values ranged from 0.70 (2006–2010 Roswell heifer model) to 0.98 (2010–2014 Mandan steer model).

Feeder cattle futures coefficients were, as expected, positive and statistically significant ($\alpha = 0.05$) for 97% of the estimated hedonic models. Expectations of the effect of weight on feeder cattle transaction price generally held based on coefficients for the feeder futures to weight ratio and feeder futures to weight squared ratio. For nearly 95% of models, lighter-weight animals experienced higher transaction prices, with transaction price decreasing at a decreasing rate with increasing animal weight. Increases in the feeder cattle to corn futures ratio result from either increases in feeder futures price or decreases in corn futures price, both of which we expect to result in increased feeder cattle transaction prices. As such, we expect a positive relationship between this variable and transaction price. Our expectation was generally met, as 62% of models exhibited a positive and statistically significant coefficient for the feeder to corn futures ratio. Interactions of the feeder to corn futures ratio with 450-549 pound, 550-649 pound, and 650-749 pound categorical weights were positive and statistically significant for 51%, 45%, and 38% of models, respectively, meaning that lighter-weight cattle more often had statistically different feeder futures to corn futures ratio coefficients than the default 750-849 pound animal. The impact of the feeder-corn futures ratio on transaction price was generally greater for lighter-weight cattle. For 72% of models, the magnitude of the categorical weight interaction term coefficient decreased as categorical weight increased.

Expectations of the effect of lot size on feeder cattle transaction price generally held based on coefficients for headcount and headcount squared. Large lot sizes realized higher prices at a declining rate for 70% of hedonic models. Categorical variables for February, March, April, and May sales were positive and statistically significant for 87%, 92%, 90%, and 82% of models relative to the January default, respectively. September, October, November, and December sale variables were negative and statistically significant for 73%, 94%, 98%, and 81% of models, respectively. Statistical significance of categorical grade variables varied, with the Medium & Large #1 coefficient being the only grade that was generally positive across all models relative to the default Medium & Large #1-2 animal. The categorical variable for comments typically associated with a premium in transaction price exhibited a positive and statistically significant coefficient for 93% of models, while the categorical variable for comments typically associated with a discount exhibited a negative and statistically significant coefficient for 90% of models, as expected.

Basis Variation

Using hedonic pricing model coefficients, we predicted unique out-of-sample transaction prices for individual feeder cattle lots. Each lot's predicted price was calculated using lot-specific sex and market location hedonic pricing model coefficients from the previous 5 year's model. For instance, 2018 Salina steer predicted transaction prices are a function of the 2013–2017 Salina steer hedonic model coefficients and each lot's specific characteristics and market conditions. Using out-of-sample price prediction errors, mean absolute errors (MAE) were calculated with equation (12) for each location, sex, month, and weight class. This resulted in more than 23,000 out-of-sample MAE calculated values for both steers and heifers, comprised of unbalanced panel and time series of out-of-sample MAE observations across the 32 markets, four weight classes, and 22 years. Equation (13) was estimated separately for steers and heifers to determine the impact of market conditions and feeder cattle characteristics on MAE values. Results are reported in Appendix Table C1.

The models explained 46%-47% of variability in MAE. Monthly average feeder cattle futures had a small positive and statistically significant impact on MAE for steers, but a negative and statistically significant impact for the heifer model. A $1 per hundredweight increase in feeder futures resulted in a $0.02 per hundredweight increase in feeder steer MAE values and a $0.05 per hundredweight decrease in feeder heifer MAE. This implies as feeder cattle price levels rise, unexplained feeder steer (heifer) cash price variation from feeder futures increases (decreases). In other words, higher price levels result in higher (lower) feeder steer (heifer) basis risk. We do not have an explanation for the difference in sign between steers and heifers associated with feeder futures prices, but the impacts are economically small suggesting feeder price levels are not a major determinant of MAE. Though previous literature has not used futures prices as a right-hand-side variable in estimating feeder cattle basis risk, Garcia, Leuthold, and Sarhan (1984) found a positive and statistically significant impact of the consumer price index on live cattle basis risk for December and June contracts, indicating higher overall prices result in higher basis risk.

Monthly average corn futures had a negative and statistically significant impact on MAE for both steer and heifer models. A 1 cent per bushel increase in corn futures resulted in slightly less than a $0.01 per hundredweight decrease in MAE for both sexes. This suggests corn price level increases reduce unexplained cash price variation from feeder futures, or basis risk, but not at an economically important magnitude. Previous basis literature has not implemented corn futures as an independent variable in estimating feeder cattle basis risk. However, Leuthold (1979) found an inverse and statistically significant relationship between corn price and live cattle basis for a nearby contract, with a $1 per bushel increase in corn price lowering basis by $1.33 per hundredweight. Similarly, Parcell, Schroeder, and Dhuyvetter (2000) found a $1 per bushel increase in the nearby corn futures price resulted in $0.75, $0.82, and $0.90 per hundredweight declines in live cattle basis for Colorado, Kansas, and Texas, respectively.

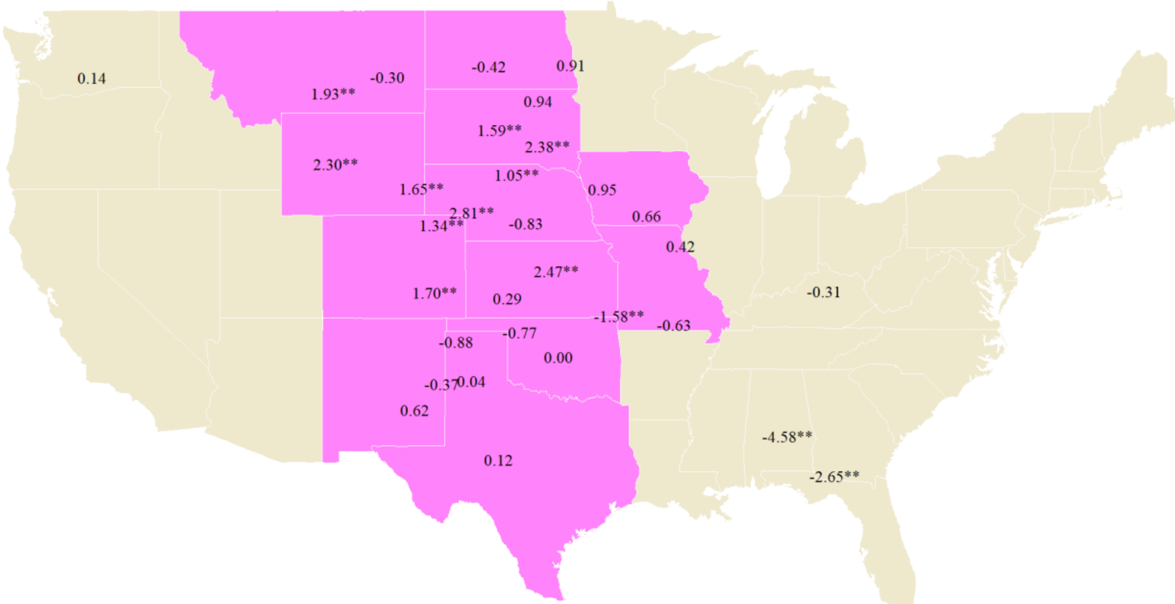
Monthly average feeder cattle implied volatility had a positive and statistically significant impact on feeder steer and heifer MAE. A 1 percentage point increase in feeder cattle annualized implied volatility was associated with a $0.33 ($0.51) per hundredweight increase in steer (heifer) MAE. Intuitively, elevated volatility in the feeder cattle market would increase basis risk. This is the first study we are aware of directly estimating this impact.

Monthly average corn implied volatility had a negative and statistically significant impact on feeder steer and heifer MAE. A 1 percentage point increase in corn annualized implied volatility resulted in a $0.05 ($0.11) per hundredweight decrease in steer (heifer) MAE. We anticipated the impact of corn implied volatility on MAE to be positive, as corn market uncertainty would lead to more variation in feeder cattle markets. Though the opposite signs were observed, the economic impacts were small.

The impact and statistical significance of categorical location variables on MAE values varied.[6] Figure 7 and 8 depict location coefficients relative to an Oklahoma City default for feeder steers and heifers, respectively. Location coefficients in the steer model ranged from -4.58 (Montgomery, AL) to 2.81 (Ogallala, NE), with 13 locations having statistically different MAE than Oklahoma City. Location coefficients in the heifer model ranged from -1.92 (Thomasville, GA) to 4.32 (Aberdeen, SD), with 24 locations having statistically different MAE than Oklahoma City. Relative to Oklahoma City, MAE from Southwest Kansas into the Texas Panhandle were generally not statistically different. Markets to the north and northwest (e.g., Billings, Riverton, Fort Pierre, Ogallala, etc.) tended to have statistically higher MAE than Oklahoma City while out-of-Index markets to the southeast (i.e., Montgomery and Thomasville) had statistically lower MAE.

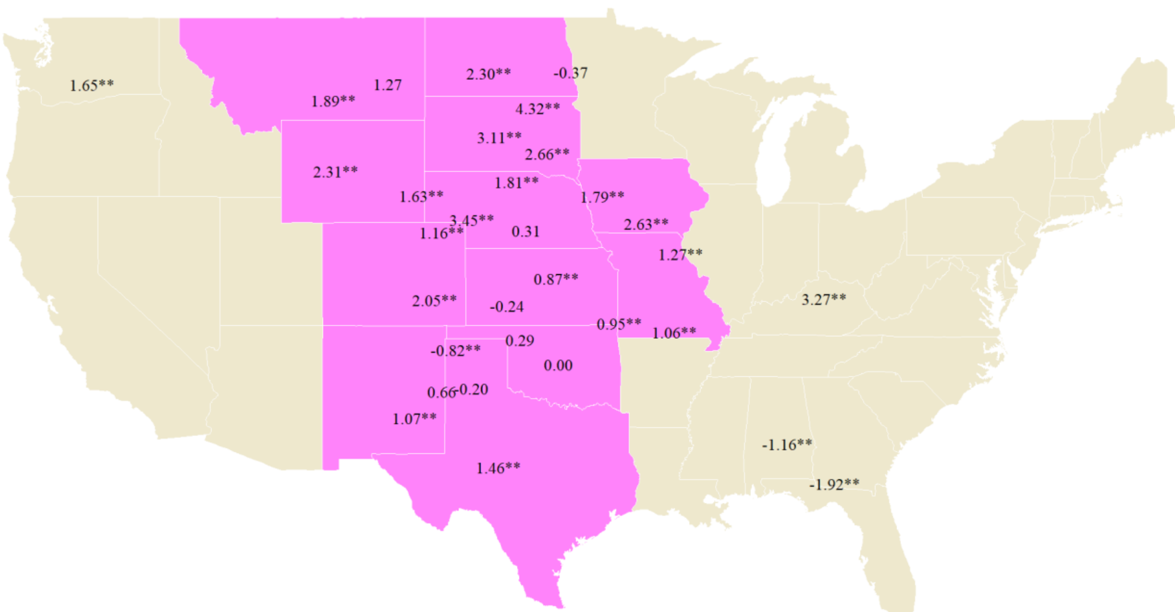
[6] Certain markets (e.g., Miles City, Aberdeen, Montgomery, and Lexington) exhibit substantial differences in categorical location coefficients between steers and heifers. Limited observations in the out-of-sample period for these markets (with available years being some of the most volatile) makes interpretation of location effects less certain.

Figure 7. Feeder Steer MAE Model Location Coefficients (Base = Oklahoma City, OK)



** Indicates statistical difference from Oklahoma City (alpha = 0.05).

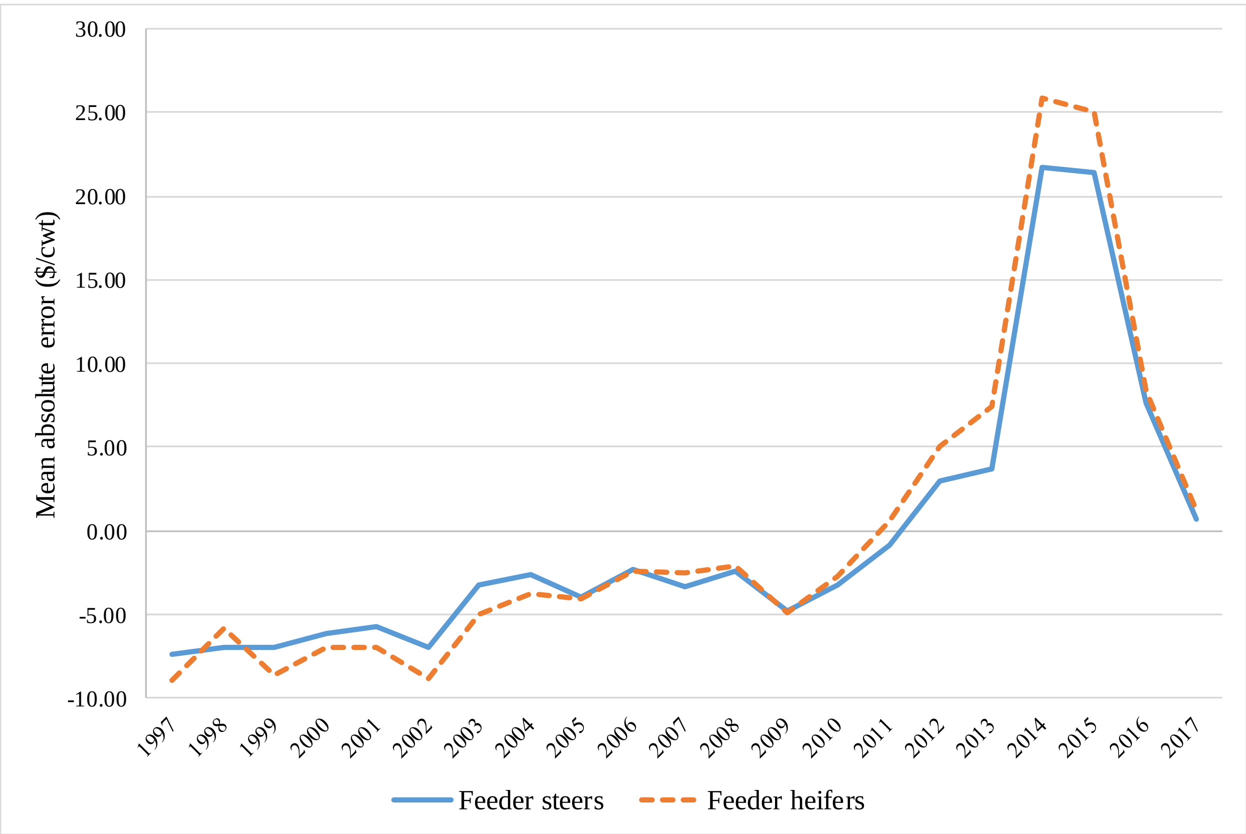
Figure 8. Feeder Heifer MAE Model Location Coefficients (Base = Oklahoma City, OK)



** Indicates statistical difference from Oklahoma City (alpha = 0.05).

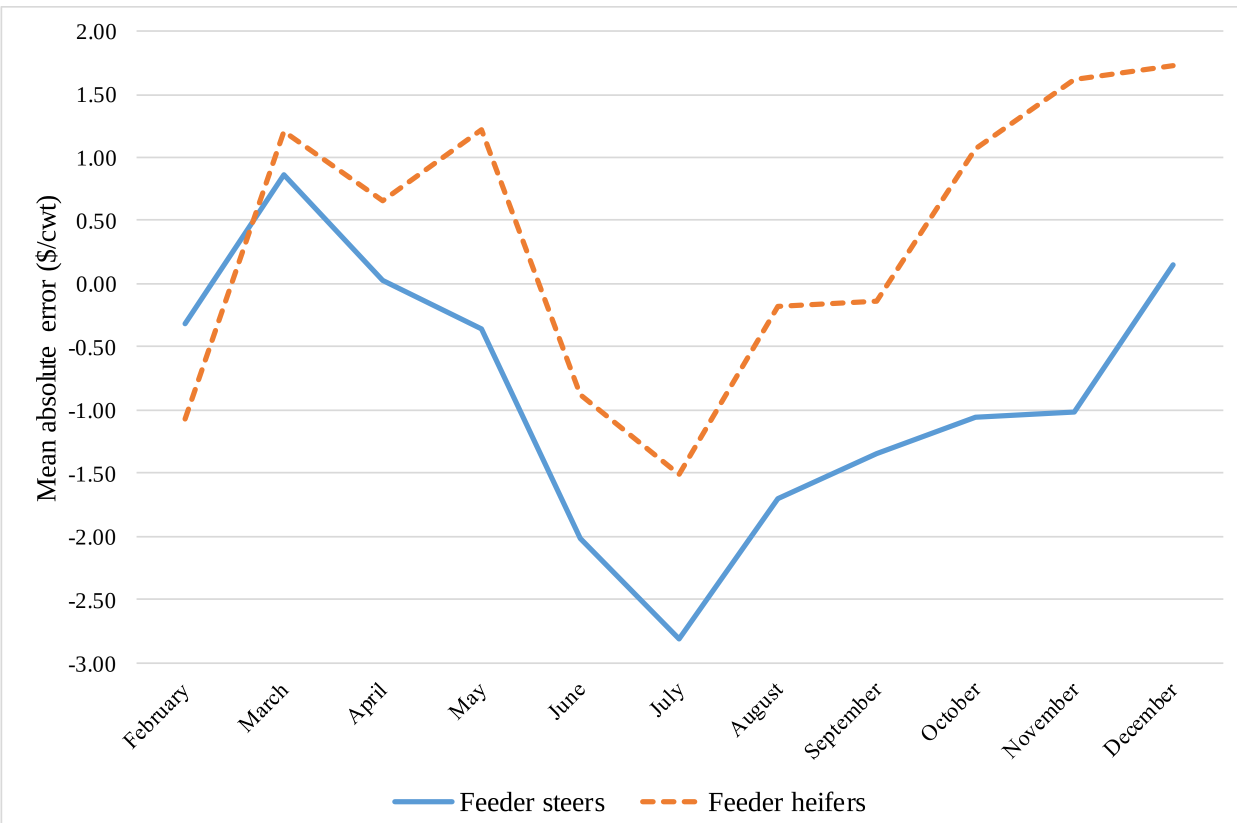
All categorical year coefficients were statistically different than the default 2018, with the exception of 2011 and 2017 for the steer model and 2011 for the heifer model. Feeder steer and heifer MAE slowly increased from 1997 to 2013, elevated sharply to around $20-26 per hundredweight in 2014–2015, and then declined post-2015. Relatively high MAE in 2014–2016 corresponds with historic price movements in the cattle market during the time period. However, addressing industry concerns (e.g., National Cattlemen's Beef Association, 2016; Peel, 2020), economically significant declines in MAE post-2015 and a statistically insignificant 2011 categorical variable suggest 2018 basis risk returned to levels similar to 2011. Figure 9 depicts categorical year coefficients of the feeder steer and heifer MAE models, highlighting basis risk changes over time.

Figure 9. Feeder Steer and Heifer MAE Model Categorical Year Coefficients (Base = 2018)



Feeder steer and heifer models exhibited seasonality in MAE. Steer MAE was not statistically different than the January base during the winter and spring months (with the exception of March), but was economically and statistically significantly lower in the summer and fall (falling to $2.81 per hundredweight lower than the January base in July). Relative to January, heifer MAE was economically and statistically significantly higher in the spring, lower in the early summer months, and higher in the fall and early winter (rising to $1.72 per hundredweight over January in December). Patterns in categorical month coefficients suggest basis risk was lower in the summer and fall for feeder steers, and was lower in the early summer but higher in the spring, fall, and early winter for heifers. Figure 10 depicts categorical month coefficients of the feeder steer and heifer MAE models, illustrating seasonal changes in basis risk.

Figure 10. Feeder Steer and Heifer MAE Model Categorical Month Coefficients (Base = January)



All categorical weight variables were statistically significant for feeder steer and heifer MAE models. Variables for 450-549 pound (*FIVE*) cattle were economically significantly higher than the default 750-849 pound animal with coefficients of $4.48 and $1.96 per hundredweight for steers and heifers, respectively. This was expected as cash prices of lighter-weight animals move differently than those of the heavier animals specified in the feeder futures contract and, as such, basis risk would be higher than animals meeting contract weight specifications. We also anticipated a positive relationship between 550-649 pound (*SIX*) categorical weight and MAE for the same reason. However, the opposite sign was observed with the steer (heifer) model having a coefficient $0.77 ($0.95) per hundredweight lower than the default 750-849 pound animal. Coefficients were also economically significantly lower for 650-749 pound (*SEVEN*) categorical weight with the steer (heifer) model having $1.48 ($1.23) lower MAEs on average relative to 750-849 pound cattle. This result was also surprising, as we expected basis risk to be either not statistically different or slightly higher for the lighter weight category. Feeder steer MAE exhibited substantial differences across weight, with 450-549 pound steers having the largest economic impact on MAE (by as much as three times the impact of other categorical weight). Calf sales account for most 450-549 pound steer transactions, while transactions of 650-749 pound steers are from calf sales or from cattle leaving a backgrounding operation. This suggests that impact of weight on MAE may depend on where cattle are in the production cycle.

Conclusions

Basis predictability is essential for hedgers using the feeder cattle futures contract as a price risk management tool. Unexpected variation in basis adversely affects feeder cattle futures hedging performance. Historic cattle price movements in 2014–2015 led to industry concerns over undue basis risk and the effectiveness of livestock futures contracts as hedging instruments. This study analyzed feeder cattle basis risk, implementing a comprehensive set of transaction-level data. We quantified market factors and lot characteristics associated with basis risk.

Futures market variables of nearby feeder cattle and corn futures and corn implied volatility, while statistically significant, had little economic impact on feeder cattle basis risk. Conversely, feeder cattle implied volatility exhibited statistically and economically significant impacts on basis risk, with a 1 percentage point increase in annualized implied volatility resulting in a $0.33 ($0.51) per hundredweight increase in feeder steer (heifer) basis risk. Previous literature has not addressed the impact of option market implied volatility on basis risk and our results indicate it is an important determinant.

Feeder cattle basis risk varied across geographic locations; generally being higher for markets to the north and northwest relative to Oklahoma City, similar in the Southern Great Plains, and lower in the Southeast. Seasonality was also present in feeder cattle basis risk, with steer basis risk being statistically and economically significantly lower in the summer and fall months, relative to January, and heifer basis risk being lower in the early summer but higher in the spring, fall, and early winter. This suggests hedgers can anticipate elevated basis variability during certain times of year. Lighter-weight feeder cattle had greater basis risk than cattle closer to meeting contract specifications (even after adjusting for differing hedge ratios).

Basis risk changed over time, being $7-9 per hundredweight lower in 1997 relative to 2018 and gradually increasing to $4-7 per hundredweight higher in 2013. Basis risk experienced historically high levels in 2014–2016, where it increased to $21-26 per hundredweight higher than 2018. However, basis risk declined post-2015, returning to levels similar to 2011 by 2018. Though basis risk was historically high in 2014–2016 and questions regarding undue basis variability arose, this likely resulted from overall cattle market disequilibrium as the market was changing rapidly to evolving market information. We see no feeder futures contract specifications that could have been modified to improve basis risk during that unprecedented time period. Our results indicate the viability of the feeder cattle contract as a risk management tool remains similar to pre-2014, though continued assessment and discussion between industry users and contract designers is necessary to ensure successful future performance.

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Appendix A - Example Estimated Hedge Ratios for Hedging Feeder Cattle in Feeder Cattle Futures

Table A1. San Angelo, TX Steers

	500 lb.			600 lb.			700 lb.			800 lb.		
Year	Agg.	Uncond.	Cond.	Agg.	Uncond.	Cond.	Agg.	Uncond.	Cond.	Agg.	Uncond.	Cond.
2006	1.26[7]	1.22	1.23[8]	1.13	1.12	1.14	1.07	1.07	1.07	0.98	1.03	1.04
2007	1.17	1.22	1.24	1.08	1.12	1.13	1.05	1.06	1.06	0.98	1.02	1.02
2008	1.10	1.19	1.19	1.02	1.10	1.09	1.02	1.04	1.02	0.97	1.00	0.98
2009	0.99	1.17	1.15	0.96	1.08	1.06	0.96	1.02	1.00	0.94	0.99	0.97
2010	0.92	1.11	1.09	0.89	1.02	0.99	0.92	0.96	0.94	0.93	0.93	0.91
2011	0.89	1.08	1.05	0.87	0.99	0.96	0.89	0.94	0.90	0.92	0.91	0.88
2012	0.93	1.05	1.00	0.90	0.96	0.92	0.88	0.91	0.87	0.87	0.88	0.84
2013	1.09	1.10	1.06	1.01	1.01	0.97	0.89	0.95	0.91	0.83	0.92	0.87
2014	1.08	1.06	1.04	0.98	0.96	0.96	0.87	0.91	0.89	0.83	0.87	0.85
2015	1.23	1.11	1.11	1.10	1.02	1.02	0.97	0.95	0.96	0.90	0.91	0.91
2016	1.29	1.14	1.15	1.14	1.04	1.05	1.01	0.97	0.98	0.93	0.92	0.94
2017	1.31	1.15	1.15	1.16	1.05	1.05	1.02	0.98	0.98	0.93	0.93	0.94
2018	1.31	1.16	1.15	1.15	1.05	1.06	1.02	0.98	0.98	0.94	0.94	0.94

Table A2. San Angelo, TX Heifers

	500 lb.		600 lb.		700 lb.		800 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	1.14	1.14	1.08	1.09	1.04	1.06	1.02	1.03
2007	1.12	1.12	1.06	1.06	1.02	1.02	0.99	0.98
2008	1.10	1.07	1.04	1.01	0.99	0.96	0.96	0.93
2009	1.07	1.04	1.02	0.98	0.97	0.95	0.94	0.91
2010	1.02	0.98	0.97	0.92	0.93	0.89	0.90	0.86
2011	0.99	0.93	0.94	0.87	0.90	0.84	0.87	0.82
2012	0.97	0.89	0.92	0.84	0.88	0.80	0.85	0.78
2013	1.04	0.98	0.98	0.92	0.94	0.88	0.90	0.84
2014	0.98	0.97	0.92	0.91	0.87	0.86	0.83	0.82
2015	1.02	1.02	0.95	0.96	0.90	0.91	0.85	0.86
2016	1.04	1.04	0.97	0.99	0.92	0.93	0.87	0.88
2017	1.05	1.04	0.98	0.99	0.92	0.93	0.88	0.88
2018	1.06	1.05	0.99	0.99	0.93	0.94	0.89	0.89

[7] Each year's hedge ratios are calculated from the previous 10 year's regression coefficients (e.g., 2006 hedge ratios are calculated from a 1996-2005 model).

[8] For illustrative purposes, unconditional and conditional hedge ratios reported in Appendix A are calculated using four separate cattle weights (500, 600, 700, and 800 lb.) and the same year's average nearby corn futures price. For example, the 2006 conditional hedge ratio for 500-pound San Angelo steers was calculated by inserting a weight of 500 lb. and the 2006 average nearby corn futures price into equation (3), whose beta coefficients are derived from a 1996-2005 San Angelo steer conditional hedonic model.

Table A3. Salina, KS Steers

Year	500 lb. Uncond.	500 lb. Cond.	600 lb. Uncond.	600 lb. Cond.	700 lb. Uncond.	700 lb. Cond.	800 lb. Uncond.	800 lb. Cond.
2006	1.23	1.23	1.15	1.15	1.09	1.09	1.05	1.06
2007	1.24	1.24	1.16	1.16	1.10	1.10	1.05	1.06
2008	1.23	1.20	1.14	1.12	1.08	1.07	1.04	1.03
2009	1.20	1.18	1.12	1.11	1.06	1.05	1.02	1.01
2010	1.18	1.16	1.10	1.08	1.04	1.03	1.00	0.99
2011	1.17	1.14	1.09	1.07	1.03	1.01	0.99	0.97
2012	1.16	1.13	1.08	1.06	1.03	1.00	0.98	0.96
2013	1.19	1.17	1.11	1.09	1.05	1.02	1.00	0.98
2014	1.18	1.17	1.09	1.09	1.03	1.02	0.98	0.98
2015	1.24	1.25	1.15	1.15	1.08	1.08	1.02	1.03
2016	1.27	1.29	1.18	1.18	1.10	1.10	1.03	1.04
2017	1.28	1.29	1.18	1.18	1.10	1.10	1.04	1.04
2018	1.28	1.29	1.18	1.18	1.10	1.09	1.04	1.04

Table A4. Salina, KS Heifers

Year	500 lb. Uncond.	500 lb. Cond.	600 lb. Uncond.	600 lb. Cond.	700 lb. Uncond.	700 lb. Cond.	800 lb. Uncond.	800 lb. Cond.
2006	1.16	1.16	1.11	1.11	1.07	1.07	1.03	1.04
2007	1.17	1.15	1.11	1.10	1.06	1.05	1.02	1.02
2008	1.14	1.11	1.08	1.05	1.04	1.01	1.00	0.98
2009	1.12	1.09	1.06	1.04	1.02	1.00	0.98	0.97
2010	1.11	1.07	1.05	1.02	1.01	0.98	0.97	0.95
2011	1.09	1.03	1.03	0.98	0.99	0.95	0.95	0.92
2012	1.07	1.01	1.02	0.97	0.97	0.93	0.94	0.90
2013	1.08	1.04	1.02	0.98	0.98	0.94	0.94	0.91
2014	1.06	1.05	1.01	1.00	0.96	0.95	0.93	0.92
2015	1.12	1.13	1.06	1.06	1.01	1.01	0.97	0.97
2016	1.14	1.15	1.07	1.08	1.02	1.02	0.97	0.98
2017	1.14	1.15	1.08	1.08	1.02	1.02	0.98	0.98
2018	1.14	1.15	1.08	1.08	1.02	1.02	0.98	0.98

Table A5. Joplin, MO Steers

Year	500 lb. Uncond.	500 lb. Cond.	600 lb. Uncond.	600 lb. Cond.	700 lb. Uncond.	700 lb. Cond.	800 lb. Uncond.	800 lb. Cond.
2006	1.22	1.23	1.13	1.14	1.07	1.08	1.03	1.04
2007	1.21	1.20	1.12	1.11	1.06	1.05	1.01	1.00
2008	1.18	1.14	1.09	1.06	1.04	1.00	0.99	0.96
2009	1.17	1.13	1.08	1.05	1.03	1.00	0.99	0.96
2010	1.14	1.09	1.06	1.02	1.01	0.97	0.97	0.93
2011	1.14	1.07	1.06	1.00	1.01	0.96	0.97	0.93
2012	1.15	1.08	1.07	1.01	1.02	0.97	0.99	0.94
2013	1.15	1.11	1.08	1.03	1.03	0.99	0.99	0.96
2014	1.13	1.11	1.05	1.03	1.00	0.99	0.97	0.95
2015	1.17	1.18	1.09	1.10	1.04	1.04	1.00	1.00
2016	1.21	1.22	1.12	1.13	1.06	1.07	1.02	1.03
2017	1.21	1.22	1.13	1.13	1.07	1.07	1.02	1.03
2018	1.21	1.22	1.12	1.13	1.07	1.07	1.02	1.03

Table A6. Joplin, MO Heifers

	500 lb.		600 lb.		700 lb.		800 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	1.17	1.19	1.11	1.12	1.06	1.08	1.03	1.03
2007	1.15	1.14	1.08	1.07	1.03	1.03	0.99	0.98
2008	1.11	1.04	1.04	0.98	0.99	0.94	0.96	0.91
2009	1.09	1.04	1.04	0.98	0.99	0.94	0.95	0.91
2010	1.08	1.01	1.02	0.95	0.98	0.92	0.94	0.89
2011	1.07	0.97	1.01	0.93	0.97	0.90	0.94	0.88
2012	1.07	0.97	1.02	0.93	0.98	0.90	0.95	0.88
2013	1.07	1.00	1.02	0.96	0.98	0.93	0.95	0.90
2014	1.04	1.02	0.99	0.97	0.95	0.93	0.92	0.90
2015	1.07	1.08	1.02	1.02	0.98	0.98	0.94	0.95
2016	1.09	1.10	1.03	1.04	0.99	1.00	0.95	0.96
2017	1.09	1.10	1.04	1.04	0.99	1.00	0.96	0.96
2018	1.09	1.10	1.04	1.04	0.99	1.00	0.96	0.96

Table A7. Billings, MT Steers

	500 lb.		600 lb.		700 lb.		800 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	1.21	1.21	1.12	1.13	1.06	1.06	1.00	1.01
2007	1.23	1.22	1.14	1.13	1.07	1.06	1.01	1.01
2008	1.21	1.16	1.12	1.07	1.04	0.99	0.99	0.94
2009	1.22	1.19	1.13	1.10	1.06	1.03	1.00	0.98
2010	1.21	1.17	1.12	1.09	1.05	1.02	0.99	0.97
2011	1.24	1.21	1.15	1.12	1.08	1.05	1.02	1.00
2012	1.24	1.20	1.15	1.11	1.08	1.04	1.02	0.99
2013	1.21	1.19	1.12	1.10	1.05	1.03	0.99	0.97
2014	1.19	1.19	1.10	1.10	1.03	1.02	0.97	0.97
2015	1.29	1.30	1.19	1.19	1.11	1.11	1.05	1.05
2016	1.32	1.33	1.20	1.21	1.12	1.12	1.05	1.06
2017	1.32	1.33	1.21	1.21	1.12	1.12	1.06	1.06
2018	1.31	1.32	1.20	1.20	1.12	1.12	1.06	1.06

Table A8. Billings, MT Heifers

	500 lb.		600 lb.		700 lb.		800 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	1.18	1.17	1.11	1.11	1.06	1.05	1.02	1.02
2007	1.20	1.17	1.12	1.10	1.07	1.04	1.02	1.01
2008	1.18	1.10	1.11	1.03	1.05	0.98	1.01	0.94
2009	1.19	1.14	1.12	1.07	1.06	1.02	1.02	0.99
2010	1.19	1.12	1.12	1.06	1.07	1.01	1.03	0.98
2011	1.21	1.13	1.14	1.07	1.09	1.03	1.05	1.00
2012	1.23	1.15	1.16	1.08	1.10	1.03	1.06	1.00
2013	1.19	1.14	1.12	1.07	1.07	1.02	1.03	0.98
2014	1.14	1.13	1.07	1.06	1.02	1.01	0.98	0.97
2015	1.18	1.19	1.10	1.11	1.04	1.05	1.00	1.00
2016	1.19	1.20	1.11	1.12	1.05	1.06	1.00	1.00
2017	1.20	1.20	1.12	1.12	1.06	1.06	1.01	1.01
2018	1.19	1.19	1.12	1.12	1.06	1.06	1.01	1.01

Appendix B - Risk Comparisons for Hedging Feeder Cattle with Unconditional versus Conditional Hedge Ratios

Table B1. San Angelo, TX Steers

	450-549 lb.			550-649 lb.			650-749 lb.			750-849 lb.		
Year	Agg.	Uncond.	Cond.	Agg.	Uncond.	Cond.	Agg.	Uncond.	Cond.	Agg.	Uncond.	Cond.
2006	10.62	10.55[9]	10.58	8.48	8.48	8.52	6.12	6.13	6.16	4.94	5.09	5.12
		-0.73[10]	*-0.45*[11]		*-0.02*	*0.45*		*0.18*	*0.61*		*3.01*	*3.57*
			0.28[12]			*0.47*			*0.43*			*0.54*
2007	9.78	9.91	9.96	7.43	7.52	7.55	6.23	6.25	6.26	5.68	5.71	5.70
		1.37	*1.94*		*1.25*	*1.68*		*0.27*	*0.34*		*0.57*	*0.49*
			0.56			*0.42*			*0.07*			*-0.08*
2008	9.46	9.80	9.81	7.09	7.27	7.26	5.80	5.85	5.83	4.60	4.59	4.58
		3.60	*3.69*		*2.55*	*2.42*		*0.80*	*0.44*		*-0.12*	*-0.31*
			0.09			*-0.12*			*-0.35*			*-0.20*
2009	8.01	8.18	8.19	7.50	7.54	7.54	5.43	5.42	5.43	4.06	4.05	4.05
		2.12	*2.18*		*0.54*	*0.50*		*-0.17*	*-0.06*		*-0.19*	*-0.07*
			0.05			*-0.04*			*0.10*			*0.12*
2010	8.18	8.19	8.12	7.23	7.25	7.19	5.90	5.91	5.86	5.06	5.04	5.01
		0.10	*-0.78*		*0.17*	*-0.64*		*0.13*	*-0.69*		*-0.49*	*-1.10*
			-0.88			*-0.81*			*-0.82*			*-0.61*
2011	13.73	13.97	13.89	11.64	11.74	11.68	9.93	9.98	9.93	8.07	8.04	8.01
		1.79	*1.20*		*0.85*	*0.33*		*0.50*	*-0.07*		*-0.36*	*-0.81*
			-0.58			*-0.52*			*-0.56*			*-0.45*
2012	14.69	14.30	14.35	12.32	12.09	12.15	9.89	9.80	9.85	8.14	8.11	8.14
		-2.68	*-2.31*		*-1.92*	*-1.40*		*-0.96*	*-0.47*		*-0.37*	*-0.03*
			0.38			*0.53*			*0.50*			*0.35*
2013	14.84	14.86	14.68	11.94	11.96	11.80	8.55	8.73	8.59	7.84	8.08	7.95
		0.09	*-1.08*		*0.15*	*-1.21*		*2.12*	*0.52*		*3.17*	*1.45*
			-1.17			*-1.35*			*-1.57*			*-1.66*
2014	19.70	18.84	18.78	15.75	15.19	15.14	11.94	11.67	11.63	8.49	8.61	8.67
		-4.38	*-4.69*		*-3.51*	*-3.83*		*-2.20*	*-2.60*		*1.36*	*2.14*
			-0.33			*-0.33*			*-0.40*			*0.77*
2015	28.49	29.28	29.31	23.13	23.60	23.55	16.00	16.06	16.05	11.36	11.30	11.26
		2.75	*2.85*		*2.02*	*1.80*		*0.39*	*0.30*		*-0.56*	*-0.92*
			0.09			*-0.22*			*-0.10*			*-0.36*
2016	15.02	16.59	16.64	11.11	12.18	12.14	8.44	8.88	8.88	6.68	6.97	7.04
		10.45	*10.81*		*9.57*	*9.23*		*5.23*	*5.13*		*4.26*	*5.28*
			0.33			*-0.32*			*-0.10*			*0.98*
2017	15.07	14.00	13.98	13.14	12.46	12.51	10.92	10.67	10.69	8.85	8.88	8.94
		-7.10	*-7.24*		*-5.16*	*-4.79*		*-2.31*	*-2.09*		*0.30*	*0.98*
			-0.15			*0.39*			*0.23*			*0.68*
2018	19.30	18.68	18.66	15.05	14.66	14.68	11.12	10.99	10.98	8.87	8.87	8.88
		-3.19	*-3.29*		*-2.58*	*-2.48*		*-1.24*	*-1.24*		*-0.07*	*0.10*
			-0.11			*0.10*			*0.00*			*0.16*

[9] Hedging risk is in units of dollars/cwt.
[10] Percent change in hedging risk from unconditional hedge ratios compared to aggregate hedge ratios.
[11] Percent change in hedging risk from conditional hedge ratios compared to aggregate hedge ratios.
[12] Percent change in hedging risk from conditional hedge ratios compared to unconditional hedge ratios.

Table B2. San Angelo, TX Heifers

	450-549 lb.		550-649 lb.		650-749 lb.		750-849 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	9.69	9.74 *0.51*[13]	8.87	8.91 *0.55*	5.12	5.14 *0.40*	4.73	4.73 *0.12*
2007	7.91	7.91 *0.04*	6.46	6.45 *-0.06*	5.09	5.08 *-0.05*	3.77	3.76 *-0.19*
2008	8.10	8.07 *-0.32*	6.58	6.55 *-0.53*	5.24	5.22 *-0.31*	3.88	3.86 *-0.61*
2009	7.28	7.30 *0.20*	5.57	5.58 *0.28*	5.00	5.01 *0.25*	3.85	3.86 *0.14*
2010	8.62	8.47 *-1.74*	9.32	9.24 *-0.89*	5.52	5.48 *-0.73*	5.62	5.60 *-0.40*
2011	12.28	12.14 *-1.09*	9.31	9.20 *-1.23*	8.17	8.09 *-0.96*	7.01	6.97 *-0.52*
2012	14.59	14.67 *0.56*	10.94	11.07 *1.17*	8.69	8.78 *1.03*	6.56	6.59 *0.39*
2013	13.44	13.19 *-1.85*	10.44	10.21 *-2.21*	8.99	8.80 *-2.08*	7.91	7.68 *-2.95*
2014	16.15	16.05 *-0.64*	12.88	13.00 *0.93*	14.02	14.15 *0.98*	10.11	10.21 *0.93*
2015	26.46	26.47 *0.03*	19.08	19.01 *-0.35*	14.46	14.43 *-0.17*	11.88	11.87 *-0.09*
2016	13.11	13.36 *1.94*	8.42	8.30 *-1.48*	7.42	7.31 *-1.40*	6.09	6.06 *-0.54*
2017	11.68	11.63 *-0.38*	9.26	9.34 *0.81*	8.08	8.12 *0.50*	8.11	8.11 *0.04*
2018	14.76	14.73 *-0.25*	11.55	11.57 *0.21*	10.61	10.62 *0.11*	9.26	9.25 *-0.08*

[13] Percent change in hedging risk from conditional hedge ratios compared to unconditional hedge ratios.

Table B3. Salina, KS Steers

Year	450-549 lb. Uncond.	450-549 lb. Cond.	550-649 lb. Uncond.	550-649 lb. Cond.	650-749 lb. Uncond.	650-749 lb. Cond.	750-849 lb. Uncond.	750-849 lb. Cond.
2006	14.92	14.94	12.58	12.60	8.80	8.81	5.83	5.82
		0.17		*0.10*		*0.07*		*-0.06*
2007	10.54	10.51	10.28	10.27	7.60	7.60	5.06	5.07
		-0.27		*-0.10*		*-0.03*		*0.03*
2008	9.87	9.83	9.32	9.31	7.62	7.62	5.84	5.85
		-0.39		*-0.14*		*0.00*		*0.01*
2009	9.20	9.18	9.17	9.16	7.03	7.03	4.52	4.51
		-0.24		*-0.12*		*-0.04*		*-0.14*
2010	8.55	8.53	8.34	8.32	6.08	6.10	4.46	4.47
		-0.21		*-0.27*		*0.17*		*0.28*
2011	13.94	13.90	11.60	11.57	8.66	8.62	5.71	5.70
		-0.34		*-0.23*		*-0.38*		*-0.18*
2012	14.03	14.12	14.01	14.07	8.83	8.85	6.72	6.72
		0.65		*0.39*		*0.24*		*-0.05*
2013	14.57	14.50	13.08	12.99	7.91	7.84	5.87	5.89
		-0.47		*-0.68*		*-0.91*		*0.32*
2014	16.85	16.91	17.89	17.90	17.64	17.61	9.62	9.60
		0.38		*0.07*		*-0.17*		*-0.21*
2015	23.97	23.95	20.42	20.40	15.53	15.55	10.01	10.02
		-0.11		*-0.09*		*0.10*		*0.11*
2016	18.15	17.88	13.88	13.72	12.49	12.45	7.73	7.79
		-1.47		*-1.15*		*-0.32*		*0.80*
2017	16.90	16.96	15.40	15.44	10.67	10.65	7.78	7.79
		0.40		*0.23*		*-0.17*		*0.08*
2018	18.61	18.63	17.27	17.28	13.63	13.62	9.30	9.30
		0.14		*0.07*		*-0.10*		*-0.01*

Table B4. Salina, KS Heifers

Year	450-549 lb. Uncond.	450-549 lb. Cond.	550-649 lb. Uncond.	550-649 lb. Cond.	650-749 lb. Uncond.	650-749 lb. Cond.	750-849 lb. Uncond.	750-849 lb. Cond.
2006	9.28	9.33	8.00	8.04	4.92	4.92	4.67	4.65
		0.54		*0.43*		*0.02*		*-0.45*
2007	7.79	7.75	6.95	6.93	5.48	5.48	3.72	3.71
		-0.51		*-0.32*		*-0.13*		*-0.17*
2008	6.46	6.43	5.99	5.99	4.62	4.64	4.02	4.05
		-0.46		*0.02*		*0.44*		*0.63*
2009	6.27	6.26	5.64	5.64	3.92	3.92	3.28	3.27
		-0.15		*-0.07*		*0.00*		*-0.10*
2010	6.69	6.57	5.20	5.15	4.64	4.62	3.54	3.56
		-1.77		*-0.97*		*-0.43*		*0.56*
2011	10.15	10.01	8.64	8.53	6.63	6.53	4.99	4.96
		-1.38		*-1.33*		*-1.50*		*-0.68*
2012	10.82	10.94	9.10	9.17	6.86	6.87	5.55	5.52
		1.12		*0.78*		*0.24*		*-0.45*
2013	9.99	9.85	8.30	8.18	5.65	5.64	4.70	4.78
		-1.36		*-1.47*		*-0.22*		*1.83*
2014	12.77	12.86	11.94	11.98	8.29	8.31	6.47	6.47
		0.76		*0.39*		*0.22*		*0.00*
2015	18.41	18.34	13.67	13.65	9.27	9.27	8.17	8.18
		-0.35		*-0.12*		*0.09*		*0.15*
2016	10.38	10.10	8.65	8.49	6.83	6.80	6.76	6.79
		-2.63		*-1.84*		*-0.47*		*0.44*
2017	12.78	12.86	9.62	9.66	7.35	7.36	5.67	5.67
		0.60		*0.41*		*0.05*		*-0.07*
2018	13.33	13.35	10.48	10.49	7.92	7.91	6.17	6.17
		0.15		*0.07*		*-0.06*		*0.00*

Table B5. Joplin, MO Steers

Year	450-549 lb. Uncond.	450-549 lb. Cond.	550-649 lb. Uncond.	550-649 lb. Cond.	650-749 lb. Uncond.	650-749 lb. Cond.	750-849 lb. Uncond.	750-849 lb. Cond.
2006	12.74	12.78 *0.29*	9.38	9.42 *0.41*	6.03	6.06 *0.50*	4.52	4.51 *-0.11*
2007	9.98	9.97 *-0.10*	7.44	7.43 *-0.09*	5.31	5.30 *-0.09*	4.16	4.15 *-0.12*
2008	9.61	9.52 *-0.95*	7.69	7.65 *-0.54*	5.09	5.08 *-0.27*	5.47	5.46 *-0.11*
2009	8.28	8.23 *-0.53*	7.28	7.26 *-0.19*	5.38	5.38 *0.00*	4.33	4.32 *-0.17*
2010	8.43	8.33 *-1.18*	7.37	7.30 *-0.96*	5.69	5.66 *-0.55*	3.52	3.53 *0.40*
2011	13.63	13.51 *-0.88*	10.39	10.31 *-0.79*	6.48	6.40 *-1.24*	6.59	6.57 *-0.21*
2012	14.88	15.03 *1.01*	11.02	11.12 *0.87*	8.48	8.54 *0.69*	6.28	6.27 *-0.04*
2013	15.15	15.00 *-0.99*	10.21	10.08 *-1.27*	8.54	8.48 *-0.67*	6.83	6.84 *0.21*
2014	21.37	21.48 *0.48*	16.49	16.53 *0.25*	11.47	11.47 *0.02*	9.78	9.80 *0.20*
2015	25.09	25.06 *-0.15*	19.19	19.17 *-0.11*	12.37	12.37 *-0.03*	10.92	10.93 *0.09*
2016	17.16	16.94 *-1.31*	11.87	11.69 *-1.55*	9.27	9.18 *-0.93*	7.83	7.87 *0.46*
2017	16.76	16.82 *0.41*	12.44	12.47 *0.20*	8.84	8.85 *0.06*	7.04	7.04 *0.12*
2018	17.74	17.77 *0.20*	13.18	13.20 *0.08*	9.31	9.30 *-0.05*	7.55	7.55 *0.04*

Table B6. Joplin, MO Heifers

	450-549 lb.		550-649 lb.		650-749 lb.		750-849 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	10.03	10.07	7.10	7.14	4.51	4.54	4.72	4.73
		0.36		*0.47*		*0.64*		*0.18*
2007	8.67	8.66	6.21	6.20	4.97	4.97	4.94	4.92
		-0.08		*-0.15*		*-0.09*		*-0.30*
2008	8.06	7.94	6.24	6.18	4.87	4.84	4.85	4.85
		-1.45		*-0.94*		*-0.81*		*-0.15*
2009	6.91	6.86	5.59	5.57	5.27	5.29	4.71	4.70
		-0.68		*-0.28*		*0.40*		*-0.19*
2010	7.21	7.04	5.94	5.83	5.44	5.38	5.56	5.53
		-2.43		*-1.86*		*-1.17*		*-0.62*
2011	9.75	9.48	7.77	7.56	6.66	6.51	6.33	6.26
		-2.72		*-2.74*		*-2.30*		*-1.08*
2012	11.11	11.33	8.17	8.33	6.42	6.46	7.39	7.39
		1.92		*1.92*		*0.57*		*-0.12*
2013	11.42	11.11	8.40	8.19	7.86	7.72	7.03	7.01
		-2.76		*-2.52*		*-1.82*		*-0.33*
2014	13.51	13.60	11.09	11.18	9.54	9.59	11.07	11.12
		0.68		*0.88*		*0.48*		*0.51*
2015	19.44	19.36	13.99	13.94	12.66	12.66	9.68	9.69
		-0.42		*-0.39*		*-0.04*		*0.05*
2016	11.05	10.87	8.51	8.37	7.92	7.84	8.28	8.26
		-1.63		*-1.55*		*-1.00*		*-0.18*
2017	11.01	11.07	7.88	7.91	6.77	6.80	6.98	6.99
		0.52		*0.30*		*0.36*		*0.10*
2018	13.14	13.16	10.39	10.40	8.34	8.34	8.06	8.07
		0.14		*0.07*		*0.04*		*0.03*

Table B7. Billings, MT Steers

Year	450-549 lb. Uncond.	450-549 lb. Cond.	550-649 lb. Uncond.	550-649 lb. Cond.	650-749 lb. Uncond.	650-749 lb. Cond.	750-849 lb. Uncond.	750-849 lb. Cond.
2006	13.03	13.06	11.48	11.51	7.51	7.52	5.23	5.24
		0.19		*0.22*		*0.16*		*0.15*
2007	10.08	10.06	7.89	7.88	6.03	6.02	3.86	3.86
		-0.21		*-0.18*		*-0.11*		*-0.03*
2008	9.56	9.44	9.09	9.06	6.70	6.68	4.29	4.28
		-1.23		*-0.29*		*-0.34*		*-0.21*
2009	10.09	10.07	8.23	8.23	6.44	6.43	3.52	3.51
		-0.23		*-0.06*		*-0.17*		*-0.23*
2010	10.21	10.15	7.90	7.84	5.10	5.04	3.56	3.54
		-0.63		*-0.68*		*-1.03*		*-0.63*
2011	12.09	12.01	12.11	12.02	7.91	7.86	4.96	4.94
		-0.64		*-0.74*		*-0.61*		*-0.46*
2012	13.06	13.14	10.06	10.12	8.18	8.18	8.62	8.61
		0.58		*0.58*		*0.04*		*-0.17*
2013	15.80	15.74	11.30	11.16	6.77	6.69	5.60	5.58
		-0.40		*-1.19*		*-1.16*		*-0.29*
2014	18.13	18.29	13.69	13.78	11.00	11.00	8.69	8.64
		0.88		*0.64*		*0.04*		*-0.56*
2015	28.47	28.37	21.11	21.07	14.60	14.59	9.67	9.66
		-0.35		*-0.18*		*-0.07*		*-0.11*
2016	17.12	16.77	12.56	12.30	9.67	9.55	8.94	8.87
		-2.04		*-2.10*		*-1.24*		*-0.77*
2017	18.00	18.06	13.91	13.93	8.91	8.90	7.98	7.98
		0.38		*0.10*		*-0.02*		*0.02*
2018	18.33	18.36	15.47	15.47	11.50	11.50	6.15	6.15
		0.13		*0.01*		*0.01*		*-0.02*

Table B8. Billings, MT Heifers

	450-549 lb.		550-649 lb.		650-749 lb.		750-849 lb.	
Year	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.	Uncond.	Cond.
2006	11.78	11.84	11.08	11.13	7.90	7.91	4.13	4.13
		0.52		*0.45*		*0.20*		*0.02*
2007	7.33	7.25	5.99	5.94	4.15	4.12	3.39	3.37
		-1.12		*-0.87*		*-0.61*		*-0.57*
2008	8.11	8.01	7.06	6.93	6.68	6.59	3.17	3.18
		-1.17		*-1.84*		*-1.33*		*0.51*
2009	8.51	8.50	7.43	7.45	5.09	5.09	2.92	2.92
		-0.21		*0.18*		*-0.02*		*0.07*
2010	7.10	6.93	7.10	6.93	6.79	6.73	2.89	2.93
		-2.34		*-2.35*		*-0.76*		*1.08*
2011	14.34	14.10	11.27	11.07	9.59	9.48	5.65	5.54
		-1.69		*-1.82*		*-1.13*		*-1.91*
2012	11.82	11.93	10.19	10.30	7.65	7.66	6.90	6.73
		0.96		*1.03*		*0.15*		*-2.48*
2013	11.37	11.33	9.12	8.86	6.80	6.63	5.33	5.35
		-0.32		*-2.83*		*-2.47*		*0.43*
2014	16.30	16.45	11.34	11.42	8.33	8.30	8.18	8.20
		0.93		*0.70*		*-0.32*		*0.25*
2015	24.93	24.82	19.77	19.71	14.61	14.59	12.24	12.23
		-0.41		*-0.29*		*-0.14*		*-0.05*
2016	12.40	12.17	11.71	11.56	7.87	7.87	7.68	7.70
		-1.83		*-1.28*		*0.03*		*0.21*
2017	13.79	13.82	10.61	10.62	8.29	8.28	6.80	6.80
		0.19		*0.08*		*-0.06*		*-0.01*
2018	14.29	14.30	12.93	12.94	9.03	9.02	6.18	6.18
		0.05		*0.02*		*0.00*		*-0.02*

Appendix C - MAE Analysis

Table C1. Summary of Regression Analysis for MAE of Feeder Cattle Transaction Price Predictions

	Default = 750-849 lb., Oklahoma City, January 2018	
	Mean absolute error ($/cwt)	
	Steers	Heifers
Intercept	14.03344***	18.12037***
	(1.43529)	(1.28608)
AVGFF	0.01830***	-0.05291***
	(0.00708)	(0.00635)
AVGCF	-0.00663***	-0.00740***
	(0.00136)	(0.00122)
AVGFIV	0.33269***	0.51022***
	(0.03076)	(0.02754)
AVGCIV	-0.04695**	-0.10676***
	(0.02003)	(0.01793)
LaJunta, CO	1.69812***	2.04806***
	(0.49518)	(0.44588)
Sterling, CO	1.33622**	1.15829**
	(0.59083)	(0.52678)
Denison, IA	0.94543*	1.78598***
	(0.50285)	(0.44922)
Russell, IA	0.65874	2.62901***
	(0.49937)	(0.44801)
Dodge City, KS	0.28858	-0.24281
	(0.47258)	(0.42188)
Salina, KS	2.46842***	0.87177**
	(0.48251)	(0.43086)
Joplin, MO	-1.57967***	0.95398**
	(0.47957)	(0.42825)
Palmyra, MO	0.42280	1.27402***
	(0.48061)	(0.42997)
West Plains, MO	-0.63092	1.06363**
	(0.48384)	(0.43206)
Billings, MT	1.92705***	1.88577***
	(0.47743)	(0.42409)
Miles City, MT	-0.30215	1.27043*
	(0.75241)	(0.66191)

Table C1. Summary of Regression Analysis for MAE of Feeder Cattle Transaction Price Predictions continued

Bassett, NE	1.05319**	1.81379***
	(0.51753)	(0.46212)
Kearney, NE	-0.83105*	0.30560
	(0.46803)	(0.41748)
Ogallala, NE	2.81107***	3.45182***
	(0.52462)	(0.46845)
Clovis, NM	-0.37411	0.65775
	(0.47258)	(0.42272)
Roswell, NM	0.62084	1.06788**
	(0.48142)	(0.44253)
Mandan, ND	-0.42390	2.29605***
	(0.54947)	(0.49007)
West Fargo, ND	0.90677*	-0.36641
	(0.54598)	(0.48924)
Woodward, OK	-0.77038*	0.28840
	(0.46541)	(0.41560)
Aberdeen, SD	0.94049*	4.32119***
	(0.55903)	(0.49983)
Fort Pierre, SD	1.59000***	3.10869***
	(0.49052)	(0.43878)
Mitchell, SD	2.37689***	2.65552***
	(0.49856)	(0.44471)
Dalhart, TX	-0.88079*	-0.81986**
	(0.46541)	(0.41571)
San Angelo, TX	0.12244	1.45645***
	(0.46541)	(0.41582)
Tulia, TX	0.04048	-0.19664
	(0.52694)	(0.47055)
Riverton, WY	2.30374***	2.30793***
	(0.48882)	(0.43499)
Torrington, WY	1.64578***	1.62715***
	(0.47644)	(0.42470)
Montgomery, AL	-4.57694***	-1.16402**
	(0.65202)	(0.59323)
Thomasville, GA	-2.65347***	-1.91724***
	(0.64377)	(0.60432)
Lexington, KY	-0.31295	3.26968***
	(0.75108)	(0.66739)
Toppenish, WA	0.14128	1.64657***
	(0.47258)	(0.42188)
1997	-7.35436***	-8.98679***
	(1.64982)	(1.47417)

Table C1. Summary of Regression Analysis for MAE of Feeder Cattle Transaction Price Predictions continued

1998	-6.96705***	-5.81993***
	(1.71817)	(1.53522)
1999	-7.02696***	-8.65679***
	(0.92983)	(0.83181)
2000	-6.11472***	-6.95638***
	(0.80308)	(0.71965)
2001	-5.78043***	-6.95253***
	(0.74235)	(0.66540)
2002	-6.95630***	-8.89103***
	(0.75269)	(0.67449)
2003	-3.22160***	-5.00346***
	(0.67386)	(0.60345)
2004	-2.67988***	-3.75784***
	(0.61400)	(0.55032)
2005	-3.99430***	-4.07870***
	(0.61105)	(0.54766)
2006	-2.32652***	-2.43371***
	(0.60502)	(0.54235)
2007	-3.35333***	-2.48890***
	(0.60587)	(0.54292)
2008	-2.47673***	-2.06832***
	(0.68256)	(0.61168)
2009	-4.85974***	-4.94147***
	(0.71531)	(0.64089)
2010	-3.27894***	-2.75243***
	(0.58047)	(0.52015)
2011	-0.82114	0.58979
	(0.64463)	(0.57771)
2012	2.99090***	5.00555***
	(0.62882)	(0.56375)
2013	3.68485***	7.39197***
	(0.51376)	(0.46110)
2014	21.70726***	25.91091***
	(0.58466)	(0.52404)
2015	21.38912***	25.02104***
	(0.55756)	(0.49960)
2016	7.63408***	8.40042***
	(0.40555)	(0.36375)
2017	0.65495*	1.20485***
	(0.39007)	(0.34967)

Table C1. Summary of Regression Analysis for MAE of Feeder Cattle Transaction Price Predictions continued

February	-0.31142	-1.06538***
	(0.32262)	(0.28927)
March	0.86995***	1.20970***
	(0.32808)	(0.29390)
April	0.03211	0.66173**
	(0.32179)	(0.28829)
May	-0.35877	1.21554***
	(0.34627)	(0.30977)
June	-2.01910***	-0.87658***
	(0.37130)	(0.33201)
July	-2.81389***	-1.50452***
	(0.37869)	(0.33899)
August	-1.69988***	-0.17967
	(0.36275)	(0.32547)
September	-1.34739***	-0.13526
	(0.32819)	(0.29423)
October	-1.06373***	1.07432***
	(0.32657)	(0.29302)
November	-1.01503***	1.61376***
	(0.31999)	(0.28705)
December	0.15123	1.72274***
	(0.33179)	(0.29779)
FIVE	4.48320***	1.95760***
	(0.19009)	(0.17111)
SIX	-0.77182***	-0.94503***
	(0.18960)	(0.17070)
SEVEN	-1.48014***	-1.23176***
	(0.18967)	(0.17103)
Observations	23,237	23,089
R^2	0.46139	0.47420
Adjusted R^2	0.45976	0.47260
Residual Std. Error	10.17534 (df = 23166)	9.08628 (df = 23018)
F Statistic	283.49040*** (df = 70; 23166)	296.55530*** (df = 70; 23018)

Note: Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level.

Values in parenthesis are standard errors of estimated coefficients.