How do changes in market fundamentals affect hedging in US live cattle markets?

by

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Abstract

When basis variability increases, it complicates hedging price risk management and causes hedging effectiveness to decrease. This is one reason that volatility in US live cattle basis has raised concerns over the last decade. It is vital for participants in live cattle cash markets to improve their understanding of how shifts in market conditions affect basis variability. The purpose of this analysis is to evaluate how changes in market fundamentals and price momentum impact live cattle hedging effectiveness and how the impacts vary regionally across Kansas, Nebraska, and Iowa-Minnesota. Identifying and measuring these impacts provide insights to improve the basis predictability and help manage live cattle hedging risk. This study used weekly data from June 2007 to December 2019 to estimate regional hedonic models where the dependent variable was Basis Prediction Error (the difference between actual Basis and Expected Basis), which serves as a hedging effectiveness measure, and the independent variables represent the shifts in the market fundamentals. The results show that the changes in the factors such as total head marketed in all markets, the thinness of the negotiated market, weight of the live cattle marketed, the current premium for high-quality beef, and the cost of gain have statistically significant relationships with Basis Prediction Error. It is essential to highlight that the statistical significance, direct impact, and magnitude for most of the variables vary across the regions and over time. The analysis of volatility using the parameter estimates and a one standard deviation shock to respective variables showed that the changes in current premium for high-quality beef and the changes in the cost of gain have a higher monetary impact on hedging outcome basis than other variables evaluated.

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Chapter 1 - Introduction

The CME Group live cattle futures contract is used as a risk management tool for hedgers. Hedging has benefits such as forward pricing opportunities for managing market risk, locking in profits subject to basis risk, enhancing business planning, and facilitating financing. Futures contracts allow all livestock industry sectors to hedge prices (CME Group, 2009). Livestock is a non-storable commodity, which means they are perishable products whose quality or quantity characteristics continuously change, impacting their price. Explaining basis for nonstorable commodities is complex (Leuthold, 1979).

Hedging is a risk-management tool for producers (short hedgers) or processors/ beef packers (long hedgers) who want protection against price volatility in the cash markets. Hedging in future markets involves buying or selling futures contracts, such that changes in the value of the futures position offsets value of the physical commodity due to changing prices in the local cash markets. Futures markets help with price discovery by connecting with short and long hedgers with speculators. The live cattle futures contract is a standardized agreement stating the commodity, quantity, quality, and delivery point (CME Group, 2020). There are six expiration months for the live cattle contract. Futures price and local cash price should converge during the expiration month. Commonly, futures price is not the same as the local cash price when the futures contract expires. The difference between the local cash market price and the futures price is known as the basis. Basis for nonstorable commodities should reflect local supply and demand conditions for the commodity (Leuthold, 1979).

Over the last decade, basis prediction has become more complicated, given the volatility of live cattle markets. This is especially noticeable from 2014 to 2016 when the basis variability and basis prediction error increased (Coffey et al., 2018). The portion of live cattle negotiated in cash markets has thinned over time and there has been a substantial structural shift toward alternative marketing agreements. Thinning cash markets has made it more difficult to obtain information that facilitates price discovery in the live cattle markets. However, negotiated live cattle trade has not been declining uniformly across the five major cattle feeding market regions over the 2004–2017 period (Schroeder et al., 2019). The purpose of this study is to evaluate how changes in market fundamentals and price momentum impact hedging live cattle sales and how the impacts vary regionally. Identifying and measuring these impacts will provide insights to improve the basis predictability and help manage live cattle hedging risk.

Chapter 2 - Literature Review

Volatility in the Cattle Industry

Price volatility in live cattle markets has been higher in recent years leading to concerns about structural change in the cattle industry and whether market fundamentals have changed their role as drivers of the live cattle cash and futures prices. These conditions decreased hedging effectiveness. When unexpected changes in factors lead to basis variability, this generates uncertainty for all participants of the live cattle markets. Cattle feeders, beef packers/processors, and market analysts may need to adjust and evaluate their business, marketing, hedging, and risk management strategies. Existing research has examined volatility in live cattle futures markets (Coffey et al., 2018; Couleau et al., 2017; Schroeder et al., 2019; Volkenand et al., 2018). In times of increased basis volatility, understanding how and why basis risk is changing over time and across regions becomes more critical for market analysis making decisions when hedging in live cattle markets.

A major concern over the past few years has been whether the cash and futures prices are moving together as. The National Cattlemen's Beef Association (NCBA) requested an increased oversight in the CME LC[1] futures contracts given the volatility seen from 2014 to 2016 in live cattle futures prices and focusing on algorithmic and high-frequency trading as troubling trading practices. In February 2016, in order to approach the concerns over the high volatility of the futures contract prices, the CME Group reduced the trading time and acknowledged that part of the volatility is driven by the lack of transactions in the spot market, which directly impacts the information available for the price discovery process (CME Group, 2019).

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[1] CME LC refers to CME Group Live Cattle Futures Contract

The futures contracts are the primary risk management tool for all the parties in US cattle markets looking for protection against adverse price changes (Schroeder et al., 2019). There is considerable debate regarding the causes of volatility in futures contract prices. Various studies have been done because a long-term move towards higher basis variability would directly equate to higher basis risk, which lowers hedging effectiveness, affecting the futures contract's primary purpose. Erratic basis variation reduces the futures contract's ability to transfer risk and use of the futures contract overall (Garcia & Sanders, 1996). The CME LC futures contract is used as a risk management tool to transfer the price risk. Price risk is the risk associated with unexpected price changes in the live cattle markets. Basis Risk is the risk associated with changes in the price spread between cash and futures prices (CME Group, 2020). A futures contract allows a hedger to exchange price risk for basis risk, which has lower variability.

Possible factors causing the high volatility in US live cattle markets

Kristoufek and Vosvrda (2014) evaluated 25 different commodity futures prices using data frame from 2000 to 2013 and, using their proposed Efficiency Index, found that live cattle and feeder cattle futures are less efficient than the others. In their analysis, the Efficiency Index is defined as a distance from the efficient market situation and is based on three market efficiency measures (Hurst Exponent, Fractal Dimension, and the Approximate Entropy). Even this study evaluated data before 2014, and, interestingly, the results using their methodology identifies low efficiency in cattle futures prices even before the volatility was seen in the live cattle markets. Previous studies have evaluated the possible causes or factors influencing the high basis risk and price volatility in the livestock futures markets seen between 2014 to 2018. Couleau et al. (2017)

addressed high-frequency trading as a cause of the variability in fed cattle markets, but their findings suggest that fundamentals were a driving factor of the increased variance in 2015.

Gee (2016) described some of the futures contract issues, including recent extreme volatility, which has left many producers concerned about the contract's reliability and attributes the recent volatility to thinning cash markets. Coffey et al. (2018)posited that the rapidly changing structure of the cash-fed cattle market, where negotiated trade is thinning, has contributed to live cattle futures being less informed about current cash market conditions and impacting hedging effectiveness. Schroeder and Coffey (2018) identified concerns in the thinness of cash markets, changing production practices, the composition of CME LC market participants, disaggregated commitment of traders report and liquidity, hedging entry, and exit timing risk. They also noted there have been changing fed cattle marketing methods.

Price Discovery (Cash and Futures Market Roles)

Price discovery is one of the main functions of futures markets (Garbade & Silber, 1983). Commodity futures guide carrying inventories and forecasts of expected futures prices reflecting future supply and demand conditions (Tomek, 1997). Empirical studies found that the nearby contract, on average, provides and reflects more information that helps with the price discovery process in futures markets for agricultural commodities but plays a less dominant role in the livestock market than other such as corn markets (Hu et al., 2020; Sanders et al., 2008; Schnake et al., 2012).

As the negotiated cash markets have thinned, the negotiated cash price's accuracy and reliability have been questioned and evaluated. Livestock is considered a non-storable commodity with changes over time and across regions. Pendell and Schroeder (2006) found that regional fed cattle prices became more cointegrated following the Livestock Market Reporting Act because the report provides and wide range of data available, which is used by all the market participants as well as academic researchers.

Markets participants have expressed concern about the price discovery work in negotiated markets, which is essential to connecting prices to economic factors and market fundamentals. The decline of negotiated transactions in the spot market could be detrimental to the live cattle price discovery process (Schroeder et al., 2019). These concerns of changing and ever-evolving live cattle market conditions make it essential to understand how different negotiated markets for fed cattle interact with and influence each other through the exchange of information (Coffey et al., 2019).

Several studies have tested the role and leadership of the cash market and futures market in the price discovery process (Bessler & Covey, 1991; Koontz et al., 1990; Mathews et al., 2015; Perry et al., 2005). The role of futures prices has been tested in various periods and methods using daily and weekly datasets and methods such as Granger causality, Cointegration, Error Correction Models. Results are mixed and subject to the period evaluated and the method performed in each study, suggesting that the price discovery has been varying over the years and changing across regions and periods. Schroeder et al. (2019) suggest that an efficient price discovery in the cash and futures cattle market is codependent. Thus, cash and futures markets are essential for the price discovery in live cattle markets because fundamental market information flows reciprocally between these two markets. Thinning negotiated cash trade and the sporadic nature of cash price information daily reported are not always representative of the national fed cattle market, which has made it challenging to hedge with CME LC futures contract.

Market Structural Break

Even if cash and futures prices move together, a significant structural break could mean that important supply and demand factors may have a different impact on the basis risk and prices. Structural breaks can be identified and confirmed using statistical methods, while the drivers of those structural breaks can be evaluated using hedonic models (Maddala & Kim, 1998). Structural breaks typically occur after a meaningful change to the supply chain or demand structure of a commodity.

Schroeder and Coffey (2018), in a report, submitted to the National Cattleman's Beef Association (NCBA), describe the main concerns and possible issues of the market fundamentals changes in the fed cattle industry. The report suggests that changes in regional cash market thinness and a trend towards higher quality beef may account for crucial regional price differences and are among the critical factors driving structural changes in the US Live Cattle markets. They posited that the major topic is the declining volume of the cash cattle tracings, given that negotiated cattle purchases represented 38% of total volume during 2005 but declined to 11% by 2017. The live cattle futures contract has been amended in order to approach and reflect both of these trends. In 2018 and 2019, the CME Group change the quality contract specifications of the live cattle futures contracts. Futures contract specification from 2002 until October of 2017 was 55% Choice and 45% Select. In October 2017, the contract changed to 60% Choice and 40% Select. From October 2018 until the present, the specification has been 65% Choice and 35% Select (CME Group, 2019).

Basis Variability

The term basis refers to the difference between live cattle futures prices and cash prices. Basis risk is defined as the variability in local market basis realized when a hedge is liquidated. Fed cattle market volatility has statistically and economically significant impacts on fed cattle basis risk. Basis risk varied across geographic locations and has a seasonal component. Overall, basis risk increased in 2014–2016 relative to historical records but returned to levels similar to 2011 by 2018 as depicts Figure 1.

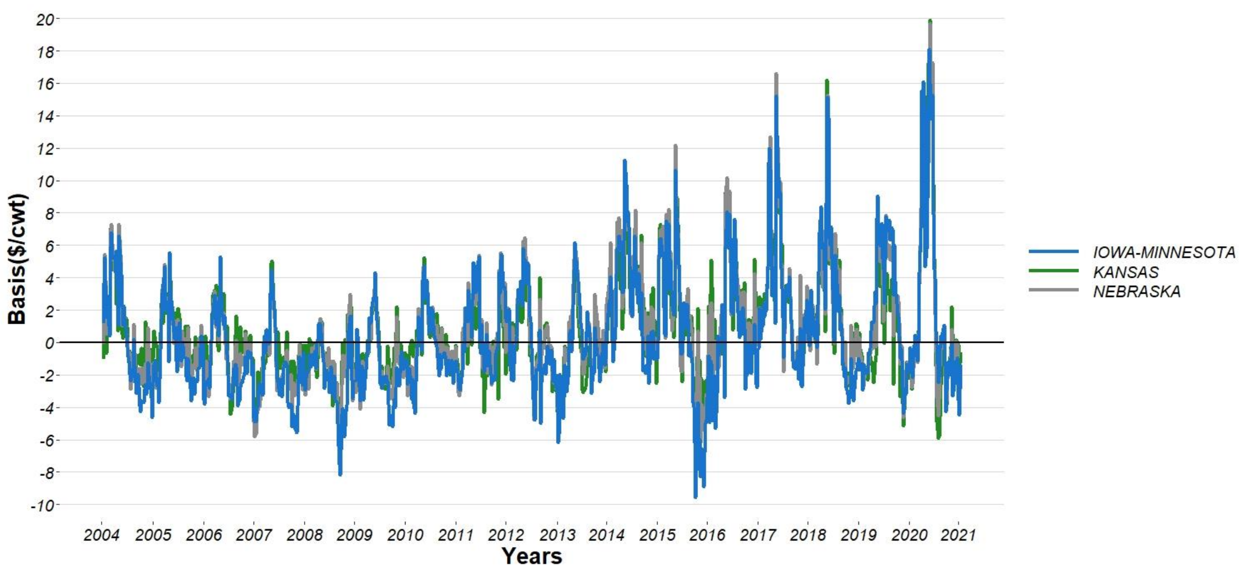

Figure 1. Weekly basis for the regions of Kansas, Nebraska, and Iowa-Minnesota

Wilder et al. (2018) identified that the basis variance for the 2014-2017 period was more than 250% larger than the basis variance during the 2004-2013 period. Cash and futures price variance was only 44% and 35% higher over the same period. Schroeder et al. (2019) empirically showed that the basis error for most of the five regions was more than doubled in 2014 compared with what it was during the period 2013 years and remained relatively high in 2015 and 2016 before settling back to about in 2017. Their finding supports the notion of a structural break in the live cattle market affecting basis variability.

The heightened basis variation can reduce the hedging effectiveness of CME Group LC futures contracts. Understanding how and why basis risk is changing over time is helpful for hedgers. Figure 1 depicts the weekly basis at the regional level in Kansas, Nebraska, Iowa-Minnesota. A predictable basis is essential for hedging in commercial operations. It is expected that live cattle cash and futures prices should converge predictably at maturity (Garcia & Leuthold, 2004).

Forecasting Basis and Fed Cattle Prices: Overview previous studies.

Previous studies have investigated forecasting live cattle basis. This section provides a selected review of research and contributions focused on empirical studies about basis in live cattle markets, with an emphasis on the price relationship, hedging, basis predictability, and discussion about their findings. Thus, we summarize their approach, methods, and findings and used that information as background to support our model and results.

Leuthold (1979) empirically demonstrates that the basis predictability was affected for supply variables changes and shows the importance of formally supply shifts on live cattle basis changes. The monthly live cattle basis for the nearby futures contracts was modeled as a function of cattle supply factors approaching contract maturity. He found that corn prices, feeder steer, and fat cattle prices were significant explanatory variables, while cattle on feed reports and seasonal variables had mixed results. His research suggests that a large portion of basis variation for contracts could be explained by cattle supply factors such as cattle slaughter, cattle on feed, corn price, feeder and fed steer prices, and seasonal variables. Building from the work of Leuthold

(1979), Tomek (1980) identified that cash prices are not necessarily related to more distant futures contract prices. His results showed that the relationship moved toward one-to-one as contract maturity approached. This suggests live cattle cash and futures prices move independently for more distant futures contracts, but the two market prices move approximately one-to-one as futures maturity nears. More recently studies such as Sanders et al. (2008) have confirmed these findings.

Garcia et al. (1984) studied basis risk, modeling variability in live cattle and live hog basis as a function of supply and demand shifts. Their research used variables such as Consumer Price Index, time to maturity contract, location, seasonal among to account for systematic risk. Their findings showed that variables representing long-term price levels and unexpected price change influence basis risk make hedging less desirable. This is important because understanding the basis and the factors which affect its behavior are fundamental to making marketing decisions. Empirical research by Naik and Leuthold (1988) studied basis risk focusing their model on how producers sell their cattle. Their study introduces maturity basis risk and a speculative component of maturity basis risk in the model. Also, showed that both maturity basis risk and a speculative component to maturity basis risk exist in live cattle basis. These articles on basis risk for non-storable commodities revealed existence of unsystematic variability.

Liu et al. (1994) focused on forecasting basis concerns specifically on the lack of convergence between cash and futures prices by employing monthly average price data to forecast live cattle basis during the month preceding contract delivery. Their findings show that open interest and lagged spread between current and two-month deferred contracts have more substantial predictive power than supply and demand and show these variables should be considered when forecasting nearby basis. They also identify open interest and delivery costs as significant factors to include in the model.

Parcell et al. (2000) analyzed the factor explain the monthly fed cattle basis variability. Their models estimated fed cattle basis as a function of lagged fed cattle basis, cattle weight, forward contracted cattle market share, corn futures prices, choice-select spread, the ratio of cattle on feed in each location, cold storage stocks. They also used a binary variable to capture monthly seasonality and represent the contract specification changed of live cattle futures contracts in 1995. Their major results indicated that a change in the Choice Select Spread affects basis positively, and they posited that both market fundamentals and seasonal components are important basis determinants. Also, they noticed that the change in the futures contract specification in 1995 did not have a significant impact on basis.

Tonsor et al. (2004) used different lengths of moving average historical basis as a predictor variable of the basis forecasts errors in an out of sample framework to evaluate which of the time-to expiration method and calendar-based method could improve the accuracy of live cattle basis prediction. They found that the optimal number of years to include in a historical average-based forecast depends on the period analyzed. Also, they suggest that including current market conditions information could improve forecasting accuracy and indicate that the use of the time to expiration approach has small effects on the forecast improvement.

Coffey et al. (2018) analyzed basis prediction errors across the Live cattle five major regions reported by Livestock Mandatory Price Reporting (LMR). Their model showed the impact of changes in factors such as the aggregate supply of cattle, market cattle weight, delivery costs, changes in the share of negotiated cash trade, and corn to live cattle price ratio had on a regional basis. Impacts were not consistent across regions. The diversity of live cattle market conditions complicates basis predictability.

As we describe in the previous studies existing research focused on live cattle basis indicates that live cattle basis is difficult to forecast or explain accurately and that results vary depending on period, location, and other factors. Relevant to the discussion on basis estimation are a few problems associated with the cash and futures prices themselves. Even though LMR has improved the data available of live cattle cash markets, the thinning cash market transaction relative to live cattle futures has raised concerns for fed and feeder futures prices in recent years. This affects the price discovery process as futures contracts are negotiated and traded every weekday (Wilder et al., 2018).

Chapter 3 - Conceptual Framework

It is essential for producers, processors, and all cattle market participants to have a thorough understanding of factors affecting live cattle price variability as they develop price expectations and make marketing decisions. Hedging in live cattle markets is the process of offsetting the risk of price changes in the local cash market by locking in a price for the same commodity in the futures markets, subject to basis risk.

Numerous studies have provided hedonic models to forecast or explain the basis for live cattle from different approaches to predict the most accurate price when futures contracts expired (Coffey et al., 2018; Liu et al., 1994; Parcell et al., 2000; Tonsor et al., 2004). Live cattle basis is modeled as a function of the factors affecting the relationship between live cattle futures prices and local cash prices over time (Parcell et al., 2000). When researchers estimate models to forecast basis, they consider major factors explaining the price variability. All these previous studies have helped hedgers to understand hedging risk better.

Reducing the hedging error (a measure of how close predicted basis was in relation to the actual basis when the futures contract expired) close to zero is a complex challenge, especially as the hedge's length increases. The hedging effectiveness can be measured using the Basis Prediction Error (*BPE*), which is the difference between the actual and expected basis. *BPE*, also known as hedging error, can be defined as a function of how current conditions of factors that affect basis have changed when compared with historical data (Δx) and other variables representing current and specific market conditions for a given week (z) this is a similar conceptual framework used by Liu et al. (1994). Then, *BPE* can be modeled as shown in equation 1.

(1) $$BPE = f(\Delta x, z)$$

Chapter 4 - Empirical Model

Data and empirical procedures

This study empirically estimates how the changes in economic factors are related to the variability of a weekly basis (the difference between cash and futures prices) and how the differences are related across three major live cattle production regions. The purpose of this type of study is to examine how the changes of different economic variables impact the hedging error, which is a different approach from similar previous studies, which evaluated the best way to forecast and explain the basis. We used the knowledge gained and similar concepts used by Coffey et al. (2018) to design our empirical model. Basis Prediction Error (*BPE*) was modeled as a function of relevant economic variables to determine how shifts in the live cattle market and contemporaneous market conditions affect basis predictability. *BPE* can be estimated as shown in equation 2.

(2) $$BPE = f(\Delta x, z, \varepsilon)$$

Where ε is a random error when the other variables remain unchanged. To estimate the model, we consider this approach and data availability of the proxy variables identified to represent the major factors influencing the live cattle market. In our models, we use data from June 2004 until December 2019. Using an updated data series will allow comparison to similar studies. We will be able to compare if the impact of the changes in the market fundamentals and current market conditions holds the same correlation as similar found by previous studies or if there have been changes in recent years.

The basis is the difference between futures price and local price in a specific market. In practice, basis is calculated and reported in absolute terms. However, it can also be represented as a ratio of cash to futures (Coffey et al., 2018; Liu et al., 1994). There are tradeoffs to this approach.

Basis reported as a ratio, or percentage, will not be as familiar to hedging practitioners. However, comparing a percentage basis might be more appropriate across a long period of time when the price levels are drastically different. As such, we calculated basis as local cash price divided by nearby futures prices and multiplied by 100 (equation 3). This method results in a basis which is cash as a percentage of the nearby futures price. A limitation when estimating the basis as a proportion is that some components that affect basis variability are likely absolute levels, such as delivery costs, and others are relative values, such as shrink costs. Calculating basis as a proportion imposes the assumption that all components impact basis in relative manner. These represent a challenge since actual impact of some components might be obscured, in terms of their effect as a source of basis variability. However, the same can be said for using the more traditional difference method for calculating basis. With the tradeoffs considered, the proportional method is used.

(3) $$Basis = \frac{Live\ Cattle\ Local\ Price}{Live\ Cattle\ Future\ Price} * 100$$

BPE was determined as the difference between the realized basis and the expected basis. The weekly expected basis was calculated using the same calendar week's average basis across the previous three years. This is a common method of basis prediction used in the cattle industry. The data series used to calculate the models starts in June 2007 until December 2020. However, the expected basis was calculated using a three-year historical average, so our data frame uses Data from June 2004 to calculate the historical average. Basis and expected basis are in percentage; hence, the *BPE* is expressed in percentage points (equation 4).

(4) $$BPE_{y,w} = \ Basis_{y,w} - (\frac{\sum_{y-3}^{y-1} Basis_{y,w}}{3})$$

Where $BPE_{y,w}$ is the basis prediction error by calendar week and year. $Basis_{y,w}$ is the observed basis in a given a calendar week and year. The expected basis is calculated as the average of $Basis_{y,w}$ from the previous three years. *BPE* is the hedging error of a specific week on the year, given that is the difference between actual and expected basis. It could be positive if the actual basis is stronger than expected or negative if the actual basis is weaker than expected.

In our method (and in the cattle industry), historical information is used to forecast basis, but current market conditions often differ from past conditions. Therefore, we define explanatory variables to represent the changes in the market conditions, relative to those imbedded in the basis prediction. For this reason, these variables were calculated similarly to *BPE*, where the change is represented as a percentage change relative to the values expected based on historical data, as we can see in the following equation 5.

(5) $$\Delta X_{y,w,r} = \frac{X_{y,w,r} - \left(\frac{\sum_{y-3}^{y-1} X_{y,w,r}}{3}\right)}{\frac{\sum_{y-3}^{y-1} X_{y,w,r}}{3}} * 100$$

Where ΔX represents changes in the live cattle market's proxy variables, *(y)* is the year, *(w)* is the week, and *(r)* is the region. The model includes five variables to represent shifts in market fundamentals: Δ*HEAD*, Δ*NEGSHARE*, Δ*WEIGHT*, Δ*CSSPREAD*, and Δ*WAGES*. These variables are described and summarized in Table 1.

In this section, each variable and what economic factor it represents is described. The variables Δ*HEAD*, Δ*WEIGHT*, and Δ*NEGSHARE* serve as proxies for specific supply changes. All the changes in these variables were calculated using regional data. The head variable (Δ*HEAD*) is the weekly average of all the live cattle traded across the four transaction types (Formula, Grid, Forwards Contract, and Negotiated). A change in *HEAD* is the difference between the number of live cattle marketed in a given calendar week and the average of the same measure in the same week across the previous three years. A positive (negative) value would indicate that the actual number of live cattle traded in all the markets is larger (smaller) than the expected number.

The Negotiated Share variable (Δ*NEGSHARE*) is the number of cattle traded through the negotiated market as a percentage of total head marketed at a regional level. A change in *NEGSHARE* is the difference in the percentage of the live cattle (beef steers and heifers), which were traded on the live negotiated market in a given calendar week and the average of the same measure from the previous three years in a given week. A negative change would indicate that the market share of the negotiated market is thinner than expected.

Similarly, the weight variable (Δ*WEIGHT*) is the average per-head weight of the dressed and live cattle marketed (Steers and Heifers) in a week. A change in the *WEIGHT* variable is the difference in the weekly per-head weight average of all the live cattle (beef steers and heifers) slaughter marketed as negotiated and the same measured in the same week based on the three-year technique. A positive change would indicate that the cattle are heavier than normal cattle for a calendar week than expected.

The variables Δ*CSSPREAD* and Δ*WAGES* were calculated using national data level. The Choice-Select Spread variable (Δ*CSSPREAD*) is a measure what the market is willing to pay for Choice versus Select beef quality. To estimate this variable was used the 600-900 pound cut-out values collected from the USDA AMS daily report LM_XB403. The price spread boxed beef cutout equivalent is expected to have different effects depending on the quality of live cattle across regions. The local cash price depends on the quality of cattle supplied, and the live cattle futures price has fixed quality specifications. It is expected that basis changes should occur due to changes in feeder expectations for being rewarded for higher quality cattle in particular areas. If the Choice-Select price spread widens, the locations with higher (lower) quality cattle will receive a larger premium (discount), and the basis would strengthen (weaken). In recent years, there have been changes in specifications in the Live Cattle Futures Contracts as to the par percentage of cattle grading Choice. We expect this variable has increased its importance because the contract specification has been changing in the past three years. A change in *CSSPREAD* is the average of Choice-Select box beef spread on a given week minus the one that is expected, which is based on the same measure in the same calendar week over the past three years. A positive change would indicate that the weekly Choice-Select Spread is wider than expected.

The variable wages (Δ*WAGES*) are used as a proxy of delivery cost. This variable represents wages paid to the drivers, which are a high percentage short distance delivery costs. A change in *WAGES* is the difference between the actual national average of hourly wages for employees of the category of Trade, Transportation, and Utilities Industry, as reported by the Bureau of Labor Statistics in a given week, and the average of the same measure across the previous three years. A positive change would indicate that the Weekly Average National Wage is higher than the expected based on the average of the last three years.

The model also includes two variables to represent current market conditions. First, it is the *CORNRATIO* variable serves as a proxy for feed costs and assesses how changing corn price affects the price hedging performance. The ratio can be interpreted as the bushels of corn equal to 1 cwt of live cattle in terms of the total value. The *CORNRATIO* serve as proxy for the marginal benefit feeders could receive from adding a pound to live cattle before slaughter. This ratio is commonly tracked and reported by cattle market and reported by cattle market analysts. We measured it contemporaneously, as shown in equation 6.

$$CORNRATIO = \frac{Live\ cattle\ local\ price}{Corn\ local\ price} \tag{6}$$

The second variable to capture the current market condition is the stochastic oscillator (*K*), a standard price momentum measure of the nearby live cattle futures prices. *K* is the ratio of the current price distance from the lowest low to the range in which the contract has recently traded.

The values are between 0 and 100. The stochastic oscillator is calculated as shown in the following equation 7.

(7) $$K = \left(\frac{FP_{current} - FP_{lowest}}{FP_{highest} - FP_{lowest}}\right) * 100$$

Where the numerator, $FP_{current}$ is the current weekly nearby futures price minus, FP_{lowest} which is the lowest low nearby futures (observed in the past 14 weeks). The denominator $FP_{highest}$ is the highest high nearby futures price observed in the last 14 weeks minus, FP_{lowest} which is the lowest low price observed during the last 14 weeks. K is bound between 0 and 100. K is a technical indicator popular among speculative traders and attempts to quantify the concept of price momentum. That is, short-term price trends that may be more extreme than fundamental analysis would suggest. The purpose of including it is to analyze whether magnitude of recent price movements is important to hedgers, considering that we are also accounting for many market fundamentals.

Live cattle supply and demand conditions are seasonal. CME live cattle futures contracts are offered for six different expiration months. These are in even calendar months. It is important to consider that the same contract expiring could perform differently across regions evaluated. For these reasons, binary variables are included to represent the six months when the futures contracts expire, using February as default. The complete model is shown in equation 8.

(8) $$BPE_{w,y,r} = \beta_0 + \beta_1 \Delta HEAD_{w,y,r} + \beta_2 \Delta WEIGHT_{w,y,r} + \beta_3 \Delta NEGSHARE_{w,y,r} + \beta_4 \Delta CSSPREAD_{w,y,r} + \beta_5 \Delta WAGE_{w,y} + \beta_6 \Delta CORNRATIO_{w,y,r} + \beta_7 K_{w,y} + \beta_8 APRIL + \beta_9 JUNE + \beta_{10} AUG + \beta_{11} OCT + \beta_{12} DEC + \varepsilon_{y,w,r} \forall r.$$

Where *(y)* is a specific year and *(w)* an individual calendar week, which can take a value of 1 to 52 by year, *(r)* represents one of the regions, which could be Kansas (KS), Nebraska (NE), Iowa/Minnesota (IA-MN). One model was estimated for each region. These regions are Livestock Mandatory Reporting (LMR) regions of Kansas, Nebraska, and Iowa-Minnesota.

Table 1. Description of variables used in the BPE models

Variable Name	Characteristic	Description
BPE	Basis Prediction Error (Δ%)	Change of the weekly average basis prediction error.
Δ*HEAD*	Head (Δ%)	Change of the weekly average of all head of live cattle sold in the four markets (Negotiated, Formula, Grid, and Contract).
Δ*NEGSHARE*	Negotiated Market Share (Δ%)	Change of the weekly average percentage of the live cattle marketed on the negotiated market.
Δ*WEIGHT*	Live Cattle Weight (Δ%)	Change of the weekly average weight of live cattle (Steer and Heifers) marketed in the negotiated market.
Δ*CSSPREAD*	Choice Select Spread (Δ%)	Change of the weekly average of the beef choice-select spread.
Δ*WAGES*	Wages (Δ%)	Change of weekly average of the wages.
CORNRATIO	Corn Ratio	Weekly average ratio (live cattle cash local price divide by the corn cash local price).
K	Stochastic oscillator (%)	Current price momentum indicator of the futures prices.
MONTH	Nearby Contract Expiring (0, 1)	Nearby contract month expiring. (February default).

Second Model

The variable *CSSPREAD* include in the first model serves as a proxy variable to evaluate how the meat quality supply's influence the final cash price and tested their effects in the *BPE*. As mentioned, the CME futures contract specifications Choice/Select percentage requirements have changed. To analyze whether the changes have altered BPE, we estimate a second model, which includes time period dummy variables corresponding to the quality specification changes. Since each region has a different distribution of quality grades, the impacts might not be uniform across regions. It should also be noted that these results should be viewed as preliminary as the postchange contracts traded with a higher par percentage of Choice cattle than contracts during the years in which the expected basis was calculated.

A second model was estimated using all the previous variables analyzed. Including one more binary variable was included to test if the *BPE* was affected by the changes in the CME futures contracts' requirements. Since the contract quality specification has been changing over the years, as we describe in table 2. Data from 2002 (and before) until October of 2017, the CME futures contract specified 55% Choice and 45% Select. In October 2017, the contract changed to 60% Choice and 40% Select. From October 2018 until the present, the specification has been 65% Choice and 35% Select (CME Group, 2019). A similar change but in opposite direction occurred in June 1995, when the futures contract specification changed from having quality requirements of 100% Choice to be reduced at 55% of Choice.

Table 2. Description of binary variables to represent changes in the futures contract specifications

Variable Name	**Characteristic**	**Description**
CHOICE55	Futures Contract 2002-2017 (0,1)	CME Live Cattle Futures Contract specifications (55% Choice-45%Select Value).
CHOICE60	Futures Contract 2017-2018 (0,1)	CME Live Cattle Futures Contract specifications (60% Choice-40%Select Value).
CHOICE65	Futures Contract 2018-present (0,1)	CME Live Cattle Futures Contract specifications (65% Choice-35%Select Value).

Notes: The variable *CHOICE55* is used as default in the model.

Considering that changes in the futures contract specifications can also be an important factor in understanding hedging errors. A premium could increase the net price received by the producer, or a discount could reduce the price. These changes could have a significant impact on the *BPE*. This second model results could provide some insight into how the contract specification changes affect the hedging ability while using a futures contract as a risk management tool to obtain protection again unexpected price changes. The complete second model is shown in the following equation 9.

$$(9) \qquad BPE_{wy} = \beta_0 + \beta_1 \Delta HEAD_{w,y,r} + \beta_2 \Delta WEIGHT_{w,y,r} + \beta_3 \Delta NEGSHARE_{w,y,r} + \beta_4 \Delta CSSPREAD_{w,y} + \beta_5 \Delta WAGES_{w,y} + \beta_6 CORNRATIO_{w,y} + \beta_7 K_{w,y} + \beta_8 APRIL + \beta_9 JUNE + \beta_{10} AUG + \beta_{11} OCT + \beta_{12} DEC + \beta_{13} CHOICE60 + \beta_{14} CHOICE65 + \varepsilon_{y,w,r} \forall r,$$

Where *(y)* is a specific year and *(w)* an individual calendar week, which can take a value of 1 to 52 by year, and *(r)* represents one of the regions, which could be Kansas (KS), Nebraska (NE), Iowa/Minnesota (IA-MN). One model was estimated for each region.

Analysis of Volatility

This analysis about volatility is based on the procedure of Marsh (2001), who used standard deviation as an approximation for volatility in explanatory variables, to ensure that the results are based on realistic changes in the economic variables which ones have been seen over time frame used in the study. Following this method and given that the variables used to estimate our model are expressed in percentage, we can analyze how unexpected economic variables affect *BPE*. In our model, the dependent and most independent variables are expressed in terms of percentage. This method allow us to report impact of market changes in terms of dollars per cwt, which is more intuitive and instructive for practitioners. The exact calculation consists of multiplying the value of the variables' coefficient by a selected futures price and then by the standard deviation of the variable selected, as shown in the following equation 10.

$$(10) \qquad Impact\ in\ BPE = \beta_i * \frac{Future\ Price}{100} * SD$$

Where Impact in *BPE* is expressed in ($/cwt), βi is the coefficient of the variable estimated in the hedonic model, *SD* is the standard deviation of the data series of each variable used to estimate the model. The set of variables representing changes in current market condition and the variables capturing the current market conditions were divide by 100.

To select the price level at which we want to evaluate the variables' volatility, we estimate the mean of the nearby Live Cattle Contract futures price over 2004–2019, which was 109.44/cwt. Based on this mean, we used a price level of $110/cwt to evaluate the impacts of a one-standard-deviation increase in the independent variables at these nearby futures price levels. To observe how each variable affects *BPE*, we assess each variable's shifts, ceteris paribus. This analysis does not consider the probability of occurrence of each change.

Chapter 5 - Data and Descriptive Statistics

The data used for this study are from the Livestock Mandatory Price Reporting (LMR) data compiled by the USDA Agricultural Marketing Service (AMS) and reported by Livestock Marketing Information Center (LMIC). The time frame of the data used for this study is from June 2007 until December 2019. However, to analyze the changes in economic variables, we need the average from three previous years, so the analysis uses data starting in June 2004. The data series of all the variables were arranged by week, having 52 weeks per year and each week finished on Friday.

The regional level data series used in this research is based on three of LMR's five regions. The data series collected at the regional level (KS, NE, IA-MN) were live cattle local prices[2] (steers and heifers), the weighted average weight of live cattle[3] (steer and heifers), live cattle negotiated market share, and corn local prices. For the datasets of the variables futures prices (highest, settle, and lowest), choice-select spread (cutout values), live cattle heads marketed in all the markets, and wages, the data were collected at the national level. The corn local price data series is average at the state level using USDA AMS databases. The variable wages were collected from the data series of the monthly average hourly earnings of employees in the trade, transportation, and utilities industry from the Bureau of Labor Statistics.

In this study, we only include three (Kansas, Nebraska, and Iowa-Minnesota) of the five major regions reported by LMR, the reason to choose these regions was because of the data

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[2] The cash local prices data series used are live free on board (FOB), which indicate that the cattle buyer is responsible for cost of delivery.

[3] The weighted average of live cattle was calculate using live and dressed cattle categories, and dressed weights were converted to live weights considering 63% dressing percentage.

availability and low rate of missing values in the weekly datasets. Less than 1% of the data was filled using monthly averages when a week data value was not present. The other two major regions reported by LMR, Colorado, and Texas are not included in this study due to the high frequency of lack of data along the years 2018-2020 in the weekly data series.

Table 3. Descriptive statistics of weekly data series 2007-2019

	Variable	Units	Mean	St. Dev.	Min	Max	N
KS	**BPE**	%	0.265	2.088	-7.231	7.97	654
	Δ HEAD	%	1.489	17.119	-39.162	63.065	654
	Δ WEIGHT	%	1.403	2.379	-3.846	10.182	654
	Δ NEGSHARE	%	-10.053	38.26	-91.4	263.88	654
	CORNRATIO	bu/cwt	27.804	8.925	13.276	60.859	654
NE	**BPE**	%	0.451	2.201	-5.911	7.831	654
	Δ HEAD	%	1.588	15.313	-42.319	81.411	654
	Δ WEIGHT	%	1.302	1.832	-6.349	7.059	654
	Δ NEGSHARE	%	-8.418	21.216	-68.336	98.205	654
	CORNRATIO	bu/cwt	28.383	9.123	13.652	59.35	654
IA-MN	**BPE**	%	0.533	2.335	-6.518	7.251	654
	Δ HEAD	%	5.429	27.356	-58.555	103.326	654
	Δ WEIGHT	%	1.032	4.122	-62.525	11.12	654
	Δ NEGSHARE	%	-4.595	16.637	-57.813	69.06	654
	CORNRATIO	bu/cwt	29.146	9.324	13.918	55.329	654
	Δ CSSPREAD	%	-0.245	2.919	-8.865	9.272	654
	Δ WAGES	%	4.516	0.901	2.378	7.206	654
	K	%	53.247	33.847	0	100	654

Notes: Δ represents the current level of a variable minus its average over the previous three years in the same calendar week. Therefore, all Δ measures are observed beginning in 2007. Δ*WAGES* is a national average based on BLS hourly wage for the transportation sector and is used for all five regions. Neither *K* nor *CORNRATIO* are calculated as differences from a three-year average and are observed for the entire time period from April 2007 to December 2020.

We also decided to do not include data from 2020 due to the COVID-19 Pandemic creating erratic changes in the market conditions as shown in Figure 2. The basis prediction errors in 2020 reflect higher values than previous years. However, we explore and estimate some models using different time periods. Those are discussed in Appendix A.

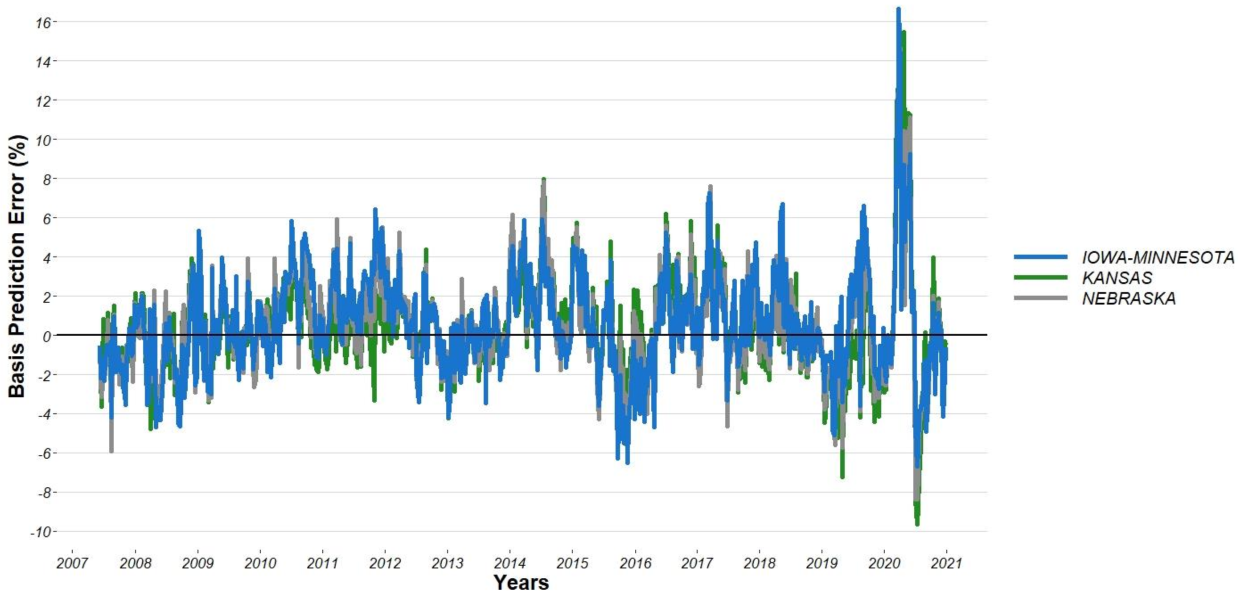

Figure 2. Basis Prediction Errors at regional level (Kansas, Nebraska, Iowa-Minnesota)

BPE is a measure of hedging accuracy, which indicates how close the expected basis estimated was to the actual basis. Figure 2 depicts the difference between the basis expected and the actual basis expressed in percentage terms. The sign of the percentage will indicate if the expected basis values were above or below the actual basis. For instance, if there is a *BPE* of 5%, our expected value estimated was 5% above the real basis when the futures contract clears. In contrast, a *BPE* of -5% indicates that the expected basis was 5% below the observed basis when the futures contract clears.

The value of BPE only indicate the distance between the actual Basis and the Expected Basis. From the standpoint of a pure risk management strategy, direction of BPE is irrelevant. However, BPE may enhance or detract from expected net depending on whether the hedgers has a short or long position. A short hedger’s net revenue will benefit from positive BPE, but a long hedger will benefit from a negative BPE. Figure 2 shown that the BPE across regions has similar behavior over the years. In recent years, BPE has bigger swings, which entails that hedging's effectiveness has decreased while increasing the risk when hedging live cattle basis. It is important to note that this does not imply there is no benefit from hedging with live cattle contract. Basis risk is still substantially lower than price risk, even though basis risk seems to have increased.

Chapter 6 - Results and Discussion

The first part of the discussion is mainly about the regional models estimated using equation (8). We will discuss each variable in terms of significance, impact, and magnitude by region. For the second part of our discussion, we present an analysis of volatility based on the model estimates' coefficient and the standard deviation of each variable.

Augmented Dickey-Fuller tests showed that the Kansas, Nebraska, and Texas data series of BPE were stationary. First, the OLS models were estimated, but, as is common in this type of study, there is autocorrelation in the errors because data series used to estimate the current values can be correlated with previous periods (e.g., Coffey et al. (2018); Tonsor et al. (2004)). We used the Durbin Watson Test to check autocorrelation in error in the OLS models, and the first-order autocorrelation was found in each (Table 4). We used the Generalized Least Squares (GLS) and Maximum Likelihood (ML) approaches to correct the autocorrelation in the errors. We test autocorrelation in the GLS models, and according to the Durbin Watson Statistic, the autocorrelation in error has been removed.

Table 4. Durbin - Watson Test in OLS and GLS models

Model	**Durbin Watson Statistic**		
	Kansas	Nebraska	Iowa-Minnesota
OLS	0.55	0.60	0.64
GLS	2.13	2.15	2.24

Note: The Durbin - Watson statistic is a value between 0 and 4. Values from 0 to 2 indicate positive autocorrelation, and values from 2 to 4 indicate negative autocorrelation. A value of 2 means that there is no autocorrelation in the model.

The main analysis is focus on the GLS models. Each region's models were estimated using 654 observations (weeks) starting from June 2007 to December 2019. Table 5 displays the models where Basis Prediction Error (*BPE*) is the dependent variable.

Table 5. Weekly Basis Prediction Error Models, June 2007 - December 2019

	UNITS	KANSAS		NEBRASKA		IOWA-MINNESOTA	
Intercept		-1.101		-0.969		-1.097	
		(0.82)		(0.93)		(0.97)	
Shifts in Market Conditions							
ΔHEAD	%	0.008	*	0.008	**	0.01	***
		(0.00)		(0.00)		(0.00)	
ΔWEIGHT	%	-0.059	*	-0.195	***	-0.019	
		(0.03)		(0.04)		(0.01)	
ΔNEGSHARE	%	0.013	***	0.012	***	0.007	*
		(0.00)		(0.00)		(0.00)	
ΔCSSPREAD	%	0.07		0.064		0.225	***
		(0.04)		(0.05)		(0.05)	
ΔWAGES	%	-0.137		0.101		0.17	
		(0.14)		(0.15)		(0.15)	
CORNRATIO	bu/cwt	0.075	***	0.035	*	0.04	*
		(0.02)		(0.02)		(0.02)	
K	%	-0.002		0.003		-0.009	***
		(0.00)		(0.00)		(0.00)	
Futures Contract Binary variable							
APRIL		-0.288		-0.289		-0.243	
		(0.36)		(0.40)		(0.39)	
JUNE		0.699	*	0.675		0.632	
		(0.42)		(0.46)		(0.46)	
AUG		0.674		0.579		0.639	
		(0.42)		(0.47)		(0.47)	
OCT		0.44		0.291		0.458	
		(0.41)		(0.45)		(0.46)	
DEC		-0.239		-0.367		-0.31	
		(0.36)		(0.40)		(0.39)	
R Squared		0.2186		0.1291		0.1730	
N		654		654		654	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the ML approach to correct for first-order autocorrelation. Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default and no binary variable for it is included. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5% and 1% levels, respectively.

This first part of the analysis discusses the impact, relationship, magnitude, and possible implication of each variable when hedging live cattle according to the results from the model estimates for each region. The interpretation of individual coefficients is the change in BPE, in terms of percentage of nearby futures price, given a 1% change in the variable evaluated. In contrast, the other variables remain unchanged *(ceteris paribus).*

The Δ*HEADS* variable was statically significant for the three regional models. The magnitude of its effects is similar in the three models. The impact of the coefficient shows a positive relationship with BPE for the three regions. The Δ*HEADS* variable represents all the cattle available to trade across markets, and according to the results, it seems to play an essential role in hedging in these regions. This implies times when more cattle are being traded across markets than expected, the *BPE* is more positive and, the basis is stronger. Our results correspond with Coffey et al. (2018) findings, who reported that the current level of cattle marketing has a statistically significantly relationship with Nebraska and Iowa's hedging, but not for Colorado, Kansas, and Texas. Interpreting this relationship is difficult due the simultaneity of the cattle feeder situation. A larger supply of live cattle should depress price. However, elevated prices in a given week would give incentive for feeders sell more cattle. In this analysis, it is impossible to determine causality. Linnel (2017), using five-markets data[4], estimated regression models to forecast errors using a combination of the shock variables to evaluate which shock variables contribute significantly to forecast errors in live cattle prices. His results showed that shocks to carcass weights, cattle on feed over 150 days, and fed slaughter numbers are significant to price forecast errors.

The Δ*NEGSHARE* variable was significant for the region of KS, NE, and IA-MN. This variable has a positive relationship with the BPE, the magnitude for KS and NE is similar, but for the region of IA-MN is smaller. The negotiated share variable represents the negotiated market's relative thinness compared total number of live cattle marketed in the region. The models show it

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[4] Five-markets data refers to the five major regions reported by LMR where the majority of negotiated fec cattle sales occur in re regions of Kansas, Nebraska, Colorado, Iowa-Minnesota and Texas-Oklahoma-New Mexico.

as a significant factor to consider when hedging. This suggests that the Δ*NEGSHARE* variable and *BPE* move together, so if the negotiated market is thinner than previous years, *BPE* is more negative, and the basis is weaker. Coffey et al. (2018) found similar results when used Negotiated Marketed Share and show it has a statistically significance relationship with *BPE* in regions of KS, NE, TX, IA-MN, and CO. Wilder (2019), using the OLS estimation method, identifies that the variable the percentage of the negotiated cash at the regional level has a significant and negative impact on basis after January 2014, but this same variable also shows significant and a positive effect on basis in the region of Kansas in years prior 2014. These results indicate that thinness of negotiated markets matters in regard to hedging effectiveness. However, as with total cattle marketed, it is not possible to determine the direction of causality. A stronger basis (i.e., higher than expected cash price) could incent feeders to put more cattle in the negotiated market. We can only say that thicker negotiated markets are consistent with more positive BPE.

The Δ*WEIGHT* variable was significant for Kansas and Nebraska's regional model. The impact of the coefficient shows a negative relationship with *BPE* for the three regions. The magnitude of the relationship is bigger in Nebraska. The Δ*WEIGHT* variable indicates if the cattle sold are heavier or not than the average weight expected. This implies that when heavier cattle coincide with more negative *BPE* more negative, then the basis is weakening. Previous studies such as Trapp et al. (1994) found that as the average weight of cattle marketed increases, it is expected that the cash price per cwt will decline. Coffey et al. (2018) findings show a negative impact of increasing weights weakening live cattle basis. They also report the significance of this factor for the region of Kansas and other regions such as Texas and Colorado. Parcell et al. (2000) found that the average marketing weight was not statistically significant for any of the basis models at the specified levels of significance for the region of Kansas, Colorado, and Texas.

The Δ*CSSPREAD* variable was significant for the regional model of Iowa-Minnesota with a significance level of 1%. For the regions of Kansas and Nebraska, the effect is not statistically different from 0. The magnitude of its effects is bigger for this region than for the other two models. The impact of the coefficient shows a positive relationship with *BPE*. The Δ*CSSPREAD* is a proxy to measures of what the market is willing to pay for Choice versus Select beef quality. Note that this is beef currently being marketed and BPE is based on live cattle currently marketed. There could exist a lag structure that better determines this relationship but we did not explore that. According to our findings, Δ*CSSPREAD* is more important in IA-MN region. This is aligned with previous results and the historical data of this northern region, which indicates feeders have access to relatively cheaper grains. This allows extending the feeder program and achieving a better beef quality grades. This implies that when there are more slaughter cattle with high quality available in the market, the *BPE* is more positive, and the basis is stronger. This could indicate that the cash price received by farmers is higher at the local market. Parcell et al. (2000) found using monthly data from 1990 to 1997 that changes in the Choice Select Spread are significant, having a positive relationship with the basis for regions of Colorado, Kansas, and Texas.

Wilder (2019) estimated models with OLS and SUR methods using regional data (KS, IA-MN, NE, CO, TX-OK-NM) and five market-weighted averaged data. His results showed that the Choice/Select Spread variable is significant and positively related to the basis. He suggests that the Choice beef will likely continue to have a large impact on cash prices and, therefore, on the basis. Highfill (2017) used monthly data from January 2003 to 2016 to estimate in-sample econometric models. He found that Choice-Select Spread was a statistically significant determinant of basis but could vary depending on the variables included in the models, also noted that this variable increased their significance post-2013.

The coefficient of Δ*WAGES* is not statistically different from zero in the three models. Its effect varies across the region, given that for the KS model, its relationship with *BPE* is negative, but the sign of the coefficient is positive for the NE and IA-MN models. The changes in the wages variable are not clear. The variable is a proxy for freight cost, but it looks like its effect is not relevant when hedging in live cattle markets. Our results differ from those of Coffey et al. (2018), who found that wages had a significant and negative relationship with basis prediction errors. Similar results were found by Liu et al. (1994) with their delivery cost proxy variable, indicating that the basis decreases as delivery cost increases. Tanners (2018) used the Diesel fuel price index as a proxy of delivery cost and found that this factor showed a significant and positive impact on *BPE* in the feeder cattle markets, it is important noticed that feeder cattle is more likely to be hauled long distances, so diesel fuel is more important in this case.

The *CORNRATIO* variable (live cattle cash price divide by local corn cash prices) was statistically different from zero for the three regions being for KS, NE, and IA-MN. The relationship between *BPE* and *CORNRATIO* variable is positive, and the magnitude of the coefficient for KS is bigger than for regions of NE and IA-MN. The *CORNRATIO* variable is a proxy of feed costs and can be interpreted as the marginal benefit of adding pounds to live cattle. This variable is a proportion not converted to percentage terms. The models show that is a significant factor to consider when hedging. For example, the ratio can increase in two ways when the corn price falls or if the cattle cash price increases. When either of these conditions happens, the BPE becomes more positive, and the basis is stronger. Previous studies have used nearby corn futures prices as feeder cost proxies, such as Parcell et al. (2000), who found that an increase in nearby corn futures price resulted in declines on the live cattle basis for Kansas, Texas, and Colorado. This is consistent with our findings. Coffey et al. (2018) found that *CORNRATIO* is significant across regions and positively related to *BPE* for the region of KS, NE, TX, CO, and IA-MN. Linnel (2017) suggests that current fed market conditions could be well represented by changes in feed data trends and carcass weights. The cattle producers have some flexibility to change their feeding plans based on current feed costs, this type of decision directly impacts the cattle supply in the market, affecting the local cash prices. On the other side processor or beef packers could increase their bid in order to give incentive for the fed cattle producer to sell. The results of these type of the decision from the supply or demand side impact directly in the local cash prices and basis prediction error could increase or decrease.

The stochastic oscillator (*K*) is statistically significant for the region of Iowa-Minnesota at 0.01 level and not for other regions. *K* has a negative relationship with *BPE* for the region of IA-MN. The *K* coefficient shows different impacts according to the location, for KS and IA-MN are negative but for NE, is positive. The *K* variable is a measure of shifts in the futures contract prices. For KS and IA-MN's case, an increment in the price of live cattle futures contracts will negatively affect *BPE*. Given the basis in this study is the division between local price and futures price, the basis will be weaker. Coffey et al. (2018) found the statistical significance of the coefficients on the Stochastic Oscillator, revealing that market trends negatively influence *BPE* in the region of KS, NE, TX, CO, and IA-MN. Similar results were found by Wilder (2019), who used the 14-day Relative Strength Index (RSI) for nearby live cattle futures which is a measure of the speed and changes of prices. This is a commonly used measure of market price momentum. His results indicate that the relationship between basis and RSI was statistically significant and negative suggesting that this measure of momentum could be a helpful estimation tool when forecasting basis.

The models include binary variables representing futures contract expiring months to capture possible seasonality effects. Six contracts are offered: February, April, June, Aug, Oct, and Dec. In general, the results showed that the binary variables do not show statistical significance across regions and along the year. An exception is found on the KS model were shows that futures contracts expiring in June is significant at 10%. In this case, finding no consistent statistical differences across contract options is reassuring. This result suggests that all the futures contracts available perform equally well for hedging prices across the year and regions.

Analysis Second Model (Equation 9)

Table 6. Weekly BPE Models Including Contract Specification Changes, 2007 - 2019

	UNITS	KANSAS		NEBRASKA		IOWA-MINNESOTA	
INTERCEPT		-2.017	**	-1.748	*	-1.64	
		-0.793		-0.932		-1	
Shifts in Market Conditions							
ΔHEAD	%	0.011	**	0.008	**	0.01	***
		-0.004		-0.004		-0.003	
ΔWEIGHT	%	-0.094	***	-0.207	***	-0.019	
		-0.033		-0.044		-0.012	
ΔNEGSHARE	%	0.011	***	0.012	***	0.008	*
		-0.002		-0.004		-0.004	
ΔCSSPREAD	%	0.116	***	0.107	**	0.238	***
		-0.041		-0.049		-0.05	
ΔWAGES	%	0.146		0.325	**	0.309	*
		-0.146		-0.165		-0.163	
CORNRATIO	bu/cwt	0.081	***	0.041	**	0.043	*
		-0.016		-0.02		-0.023	
K	%	-0.001		0.004		-0.008	**
		-0.003		-0.003		-0.003	
Futures Contract Binary variable							
APRIL		-0.33		-0.324		-0.268	
		-0.341		-0.39		-0.392	
JUNE		0.492		0.566		0.587	
		-0.387		-0.448		-0.461	
AUG		0.475		0.467		0.608	
		-0.382		-0.447		-0.467	
OCT		0.235		0.205		0.444	
		-0.376		-0.437		-0.453	
DEC		-0.276		-0.372		-0.299	
		-0.338		-0.387		-0.39	
CHOICE60		-1.37	***	-0.98		-0.017	
		-0.53		-0.636		-0.722	
CHOICE65		-3.013	***	-2.692	***	-1.732	**
		-0.568		-0.672		-0.755	
R square		0.3078		0.1692		0.1746	
N		654		654		654	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the ML approach to correct for first-order autocorrelation. Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default and no binary variable for it is included. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Comparing the results of our first (equation 8) and second (equation 9) model as described in the empirical framework, we find that the coefficient for the variables Δ*HEAD*, Δ*WEIGHT*, Δ*NEGSHARE*, Δ*CORNRATIO*, and *K* are consistent in terms of significance, sign, and magnitude across the three regions evaluated. However, in the second model, we noticed some differences specifically in the variable Δ*CSSPREAD* is significant at 5% in KS, NE, and IO-MN. The variable Δ*WAGES* shows the significance and a positive relationship with *BPE*, as we can see in Table 4 and Table 6. The Binary variables serve to represent the months when the futures contract expired show no significant impacts. The binary variables (*CHOICE60* and *CHOICE65*) representing the futures contract specification changes show significant impacts on *BPE* for IA-MN, KS and NE. These variables also have a negative relationship with *BPE,* which could indicate that when the first and second change in the contract specification happened, this had a negative impact on the *BPE*.

During 2019 and 2020, there have been external industry factors affecting the basis predictability. Hence, the second model results are difficult to ensure that the binary variables explain the effect of the changes in the futures contract specifications. There are fewer than three years of data available now since the last change in the contract specifications. It is difficult to evaluate or see the effect of the changes in such a short time. A limitation of this model is that to estimate the expected basis and the changes in five economic variables depended on a rolling average (see equation 3), Therefore, the changes in *CHOICE60* and *CHOICE65* are relative to the rolling average from the previous three years, when there were different futures contract specifications.

Parcell et al. (2000) evaluated a similar change in the quality specification in the futures contracts using data from January 1990 to July 1997 and including a binary variable in their model to capture the effect of the change in the futures contract specification in 1995 when the quality specification changed from 100% to 50% Choice. However, the variable did not show statistical significance as a factor to determine the basis for the region for Colorado, Kansas, and Texas.

Analysis of Volatility (First Model)

We show and analyze how economic variables' volatility could affect the *BPE* in monetary terms for this part of our discussion. It is important to have in mind that we perform this analysis using a live cattle futures price of $110; this value is approximately the average of the live cattle price from 2007 to 2019. Also, a 1-standard deviation shock is used as a change in one variable when the others remain the same. Unexpected shifts in market fundamental conditions and price momentum show impacts on hedging effectiveness. The variables Δ*HEADS*, Δ*WEIGHT*, Δ*NEGSHARE*, *CORNRATIO*, and Δ*CSSPREAD*, shows a consistent effect across regions, however, the variables ΔWAGES and K shows different effect according to the region. The magnitude of the effect of the change in each variable varies across regions, as depicts in Figure 3.

The variable Heads (ΔHEAD) showed that a 1-SD increase has an upward effect over BPE across the three regions studied, which implies that short hedgers' net price will increase. The larger impact is shown in the Iowa-Minnesota region, having an increment of $0.30/cwt when the negotiated market share increase 9.3%. This result gives us an insight that the IA-MN region is most sensitive to changes in the number of live cattle marketed across the three markets. For Kansas's region, the increment is $0.15/cwt and for Nebraska is $0.13/cwt.

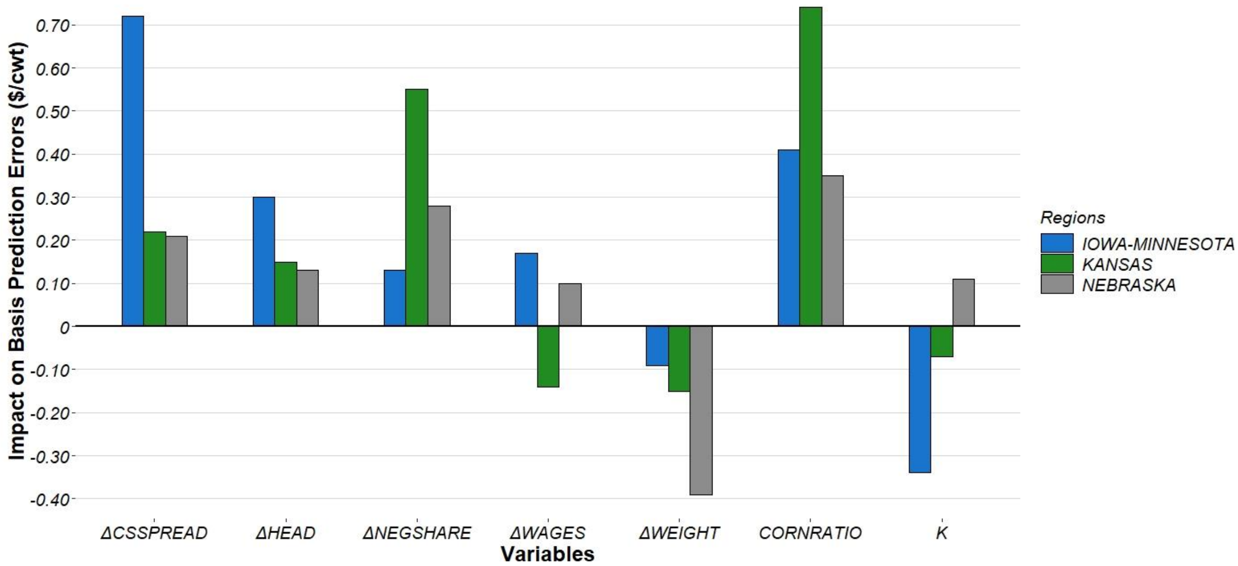

Figure 3. Impacts on BPE in monetary terms when the variables increase by 1-Standard Deviation.

The variable Weight (Δ*WEIGHT*) exhibited that a 1-SD increase has a downward effect over *BPE* across the three regions studied, which implies that short hedgers' net price will decrease relative to expectations. The region that shows a larger impact is Nebraska, reducing $0.39/cwt in the net price when the weight of the cattle traded increases by 1.83%. This implies that the NE region is more susceptible to changes in the average weights and aligns with the significance at the 1% level shown by the model's coefficient. The reduction was $0.15/cwt for the KS region, and IA-MN is $0.09/cwt.

When applying 1-SD to the variable negotiated cattle (Δ*NEGSHARE*) there had an upward effect over *BPE* across the three regions studied, which implies that short hedgers' net price will increase. The larger impact is shown in the KS region, having an increment of $0.55/cwt when the negotiated market share increases 38.26%. This indicates that the KS region is more sensitive to changes in the negotiated market's live cattle traded. For the NE region, the increment was $0.28/cwt and for IA-MN is $0.07/cwt.

The variable *CORNRATIO* had a positive impact over *BPE* across the three regions studied and presents higher effects over the *BPE* between the variables selected to estimate the model. The region that shows a larger impact is Kansas, increasing $0.74/cwt in the net price when the ratio increases 8.92%. However, the Iowa-Minnesota region increased $0.41/cwt when the *CORNRATIO* increases by 16.33%. Nebraska shows a lower increment of $0.35/cwt when the ratio increases by 9.12%. The Kansas region is more sensitive to the ratio changes because lower increments in *CORNRATIO* variable have a reduction equal to the IA-MN region. Leuthold (1979) found an inverse relationship between corn price and live cattle basis for a nearby contract, showing that when corn prices increase by $1 per bushel, this lower basis by $1.33/cwt. Parcell et al. (2000) found an increase of $1 per bushel in the nearby corn futures prices leads to $0.75, $0.82, and $0.90 per hundredweight declines in live cattle basis for Colorado, Kansas, and Texas respectively. The results from our models show consistency with the findings of these previous studies given that they used directly the corn price as variable in their model and we used a ratio.

The increase of 1-SD on the variable Choice Select Spread (Δ*CSSPREAD*) has an upward effect over *BPE* across the three regions. The larger impact is shown in the Iowa-Minnesota region, having a net price increment of $0.72/cwt when the Δ*CSSPREAD* increase by 2.9%. The increment for Nebraska is $0.21/cwt and Kansas by $0.22. These results indicate the region IA-MN benefits more than others. The Δ*CSSPREAD* variable represents the difference between wholesale boxed beef cutout values for the USDA choice select quality grades and the fact that cattle coming from northern regions achieve higher quality rates than the southern. Parcell et al. (2000) found that a $1/cwt increase in the Choice Select price spread for 700 to 850 pound boxed beef cutout equivalent strengthened basis by approximately $0.12/cwt in each of the regions.

The variable Wages ($\Delta WAGES$) show that the increase of 1-SD has an upward effect on BPE for NE and IA-MN regions, a downward effect for KS. The larger impact is shown in the Iowa-Minnesota region, having an increment of \$0.17/cwt when the wages increase by 0.9%. Moreover, for Nebraska is \$0.15/cwt. However, for the Kansas region, de reduction in the price is \$0.14/cwt. Given that the variable $\Delta WAGES$ is a proxy of the delivery cost, these results show that this type of cost has a different effect across regions.

When there is an increase of 1-SD of the Stochastic oscillator (K), the BPE is affected negatively for KS and IA-MN regions but having a positive effect on NE. The larger impact is shown in the Iowa-Minnesota region, reducing \$0.34/cwt when K increases by 33.8%. And for KS, a reduction of \$0.07/cwt in the net price. However, for the Nebraska region, the increment in the price is \$0.11/cwt. Given that the variable K is a measure of market trends, these results show that KS changes have different effects across regions and negatively affect KS.

Chapter 7 - Conclusions

The magnitude of basis error over 2014–2016 raised concerns regarding the predictability of basis and hedging effectiveness. The increased volatility in both cash and live cattle futures markets during that period represents a challenge for price risk management. Cattle market participants need to improve and update their understanding of how shifts in the market conditions affect the basis variability across geographic regions and over time. This study used regional models to estimate how the impact of changes in the market conditions affect the basis prediction error in weekly fed cattle basis for the regions of Kansas, Nebraska, and Iowa-Minnesota. The independent variables serve to represent the shifts in the market fundamentals.

Our results suggest that live cattle basis prediction errors are affected by various economic factors. The factors that have a statistically significant relationship with basic prediction errors were the variables that represent the head marketed across markets, the thinness of the negotiated market, the average weight per head of the live cattle marketed, the current premium for high-quality beef, and cost of gain. We consider these factors as important in explaining in explaining basis variability and hedging effectiveness. The model also includes contract binary variables and show that overall all the futures contracts perform equally along the year and across regions.

It is important to highlight that the statistical significance, direct impact, and magnitude for most of the explanatory variables vary across such as the Choice - Select Spread variable which has a higher magnitude impact in Iowa-Minnesota region than for Kansas or Nebraska. This is explainable since each local market has its specific conditions. Further, the variables could show different effects over time, thus vary depending on the period analyzed (see Appendix A for examples).

The analysis of volatility using the parameter estimates and a one standard deviation shock as realistic change on the variables showed that changes in the current premium for high-quality beef and costs of gain have a higher monetary impact on the basis than other variables evaluated. This study updates the knowledge regarding the role and consistency of each market fundamental factor. Understanding how basis predictability is affected by market conditions changes is essential in managing price risk by hedging

This research analyzed the hedging prediction errors seen in the period of 2007-2019 and explained how the changes in major market fundamentals affect the basis predictability. The hedging errors have been increasing in more recent years. However, this fact does not imply that the futures contracts are not beneficial when hedging. Overall, even if the basis variability has increased and had as a consequence the decreasing in hedging effectiveness in the Live Cattle markets, hedgers are still better off using the futures contracts to manage risk as basis risk is substantially lower than price risk.

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Appendix A - BPE Models Using Different Periods

The models showed in this appendix are based on equation 8. Four models were estimated using a different timeframe for each of the three regions analyzed (Kansas, Nebraska, Iowa-Minnesota). For instance, the model Kansas 16 is estimated using data from June 2007 to December 2016. The model Kansas 18 was estimated using data from June 2007 to December 2018. The model Kansas 20 was estimated using data from June 2007 until December 2020, as shown in Table A.1., Table A.2., Table A.3. Among the region and the different periods evaluated, the models seem to be similar for periods 2004- 2016, 2004-2018, 2004, 2004-2019. The model that includes data until December 2020 shows one of the major changes because the intercept is considerably higher than those shown on other models that do not include data until 2020. The intercept becomes statistically significant for these models indicating that the variability resulting from 2020 events is not captured or represented by the variables included in the model. Further studies are necessary to evaluate other factors and measure the distortions and consequences of the COVID pandemic in 2020.

Table 7. Weekly Basis Prediction Error Models, Kansas

	Units	Kansas16		Kansas18		Kansas19		Kansas20	
Intercept		-1.133		-1.153		-1.101		-3.887	***
		(0.89)		(0.85)		(0.82)		(1.088)	
Shifts in Market Conditions									
ΔHEAD	%	0.011	**	0.011	**	0.008	*	0.01	**
		(0.01)		(0.00)		(0.00)		(0.004)	
ΔWEIGHT	%	-0.11	***	-0.076	**	-0.059	*	-0.05	
		(0.04)		(0.03)		(0.03)		(0.034)	
ΔNEGSHARE	%	0.015	***	0.011	***	0.013	***	0.012	***
		(0.00)		(0.00)		(0.00)		(0.002)	
ΔCSSPREAD	%	0.055		0.019		0.07		0.101	*
		(0.05)		(0.05)		(0.04)		(0.054)	
ΔWAGES	%	-0.017		-0.086		-0.137		0.267	*
		(0.18)		(0.16)		(0.14)		(0.137)	
CORNRATIO	bu/cwt	0.092	***	0.08	***	0.075	***	0.114	***
		(0.02)		(0.02)		(0.02)		(0.029)	
K	%	-0.002		-0.002		-0.002		-0.006	*
		(0.00)		(0.00)		(0.00)		(0.003)	
Futures Contract Binary Variable									
APRIL		-0.456		-0.179		-0.288		0.126	
		(0.38)		(0.36)		(0.36)		(0.413)	
JUNE		0.075		0.531		0.699	*	0.832	*
		(0.42)		(0.41)		(0.42)		(0.498)	
AUG		0.174		0.54		0.674		0.552	
		(0.42)		(0.40)		(0.42)		(0.512)	
OCT		-0.294		0.015		0.44		0.642	
		(0.41)		(0.40)		(0.41)		(0.492)	
DEC		-0.598		-0.403		-0.239		-0.115	
		(0.37)		(0.36)		(0.36)		(0.411)	
R Squared		0.2634		0.2382		0.2186		0.2070	
N		498		602		654		706	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the ML approach to correct for first-order autocorrelation. Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default, and no binary variable for it is included. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 8. Weekly Basis Prediction Error Models, Nebraska

	Units	Nebraska16		Nebraska18		Nebraska19		Nebraska20	
Intercept		-0.555		-0.454		-0.969		-2.864	***
		(1.09)		(0.99)		(0.93)		(1.06)	
Shifts in Market Conditions									
Δ*HEAD*	%	0.009	**	0.008	**	0.008	**	0.009	**
		(0.00)		(0.00)		(0.00)		(0.00)	
Δ*WEIGHT*	%	-0.238	***	-0.173	***	-0.195	***	-0.193	***
		(0.05)		(0.05)		(0.04)		(0.05)	
Δ*NEGSHARE*	%	0.012	**	0.012	***	0.012	***	0.012	***
		(0.01)		(0.00)		(0.00)		(0.00)	
Δ*CSSPREAD*	%	-0.02		-0.016		0.064		0.076	
		(0.06)		(0.06)		(0.05)		(0.06)	
Δ*WAGE*	%	0.092		-0.026		0.101		0.361	***
		(0.21)		(0.18)		(0.15)		(0.14)	
CORNRATIO	bu/cwt	0.048	**	0.044	**	0.035	*	0.068	**
		(0.02)		(0.02)		(0.02)		(0.03)	
K	%	0.003		0.003		0.003		-0.001	
		(0.00)		(0.00)		(0.00)		(0.00)	
Futures Contract Binary Variable									
APRIL		-0.485		-0.171		-0.289		0.139	
		(0.45)		(0.41)		(0.40)		(0.44)	
JUNE		0.327		0.567		0.675		0.652	
		(0.51)		(0.46)		(0.46)		(0.52)	
AUG		-0.032		0.316		0.579		0.3	
		(0.51)		(0.46)		(0.47)		(0.53)	
OCT		-0.278		-0.075		0.291		0.222	
		(0.50)		(0.45)		(0.45)		(0.51)	
DEC		-0.639		-0.446		-0.367		-0.378	
		(0.44)		(0.40)		(0.40)		(0.44)	
R Squared		0.1164		0.1188		0.1291		0.1454	
N		498		602		654		706	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the ML approach to correct for first-order autocorrelation. Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default, and no binary variable for it is included. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Table 9. Weekly Basis Prediction Error Models, Iowa-Minnesota

	Units	IA-MN16		IA-MN18		IA-MN19		IA-MN20	
Intercept		-0.64		-0.405		-1.097		-1.758	*
		(1.23)		(1.09)		(0.97)		(1.01)	
Shifts in Market Conditions									
ΔHEAD	%	0.011	***	0.012	***	0.01	***	0.01	***
		(0.00)		0.00		(0.00)		(0.003)	
ΔWEIGHT	%	-0.011		-0.013		-0.019		-0.033	**
		(0.01)		(0.01)		(0.01)		(0.013)	
ΔNEGSHARE	%	0.009	*	0.005		0.007	*	0.008	*
		(0.01)		0.00		(0.00)		(0.005)	
ΔCSSPREAD	%	-0.0001		0.046		0.225	***	0.239	***
		(0.07)		(0.06)		(0.05)		(0.053)	
ΔWAGE	%	-0.028		-0.163		0.17		0.225	*
		(0.21)		(0.18)		(0.15)		(0.133)	
CORNRATIO	bu/cwt	0.058	**	0.065	***	0.04	*	0.06	**
		(0.03)		(0.02)		(0.02)		(0.025)	
K	%	-0.01	***	-0.009	***	-0.009	***	-0.012	***
		(0.00)		0.00		(0.00)		(0.004)	
Futures Contract Binary Variable									
APRIL		-0.169		-0.042		-0.243		0.127	
		(0.45)		(0.40)		(0.39)		(0.418)	
JUNE		0.608		0.826	*	0.632		0.742	
		(0.54)		(0.48)		(0.46)		(0.494)	
AUG		0.505		0.684		0.639		0.434	
		(0.55)		(0.49)		(0.47)		(0.503)	
OCT		0.234		0.372		0.458		0.356	
		(0.53)		(0.47)		(0.46)		(0.487)	
DEC		-0.28		-0.269		-0.31		-0.24	
		(0.45)		(0.40)		(0.39)		(0.416)	
R Squared		0.1052		0.1323		0.1730		0.1791	
N		498		602		654		706	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the ML approach to correct for first-order autocorrelation. Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default and no binary variable for it is included. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5% and 1% levels, respectively.