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Walter Ac-Pangan and Brian K. Coffey

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

Walter Ac-Pangan[1] and Brian K. Coffey[2]

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[1] Walter Ac-Pangan is a Graduate Research Assistant in the Department of Agricultural Economics at Kansas State University
[2] Brian K. Coffey is an Associate Professor in the Department of Agricultural Economics at Kansas State University

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An increase in basis variability 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. 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. This study used weekly data series to estimate regional hedonic models where the dependent variable was Basis Prediction Error, which serves as a hedging effectiveness measure, and the independent variables represent the shifts in the market fundamentals. The results suggest that a positive change in factors such as the thinness of the negotiated market and cost of gain will increase the Basis Prediction Errors. In contrast, variables such as the average weight per head of the live cattle marketed and delivery costs have an opposite influence. The analysis of the monetary impact of explanatory variables shocks showed that changes in the costs of gains have a larger monetary impact on the basis for Kansas. For Nebraska are the changes in delivery costs, and the Iowa-Minnesota region is more sensitive to changes in the current premium for high-quality beef.

Key words: hedging, basis, risk management, live cattle, future contracts.

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). 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 offset changes in the value of the physical commodity due to changing local cash prices. Futures markets also facilitate price discovery by connecting 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. It is expected that live cattle cash and futures prices should converge predictably at maturity (Garcia & Leuthold, 2004). However, futures price will generally not be the same as the local cash price at futures expiration. The difference between the local cash market price and the futures price is known as the basis.

Livestock is a nonstorable commodity, which means they are perishable products whose quality or quantity characteristics continuously change, impacting their price. Explaining basis for nonstorable commodities is complex but it is agreed that basis for nonstorables should reflect local supply and demand conditions for the commodity (Leuthold, 1979). Some market participants claim that hedging and basis prediction have become more complicated, given the volatility of live cattle markets. For example, from 2014 to 2016 basis variability and basis prediction error increased, relative to historical levels (Coffey et al., 2018).

Over the past 20 years, there have been major structural shifts in live cattle markets. One notable change is that the portion of live cattle sold via negotiation in cash markets has thinned over time. Over the same time frame, there has been a substantial structural shift toward alternative marketing agreements (formula sales). There is a concern that thinning cash markets make it more difficult to obtain timely information that facilitates price discovery in the live cattle markets. Another layer of complexity is added by the fact that negotiated live cattle trade has not declined uniformly across the five major cattle feeding market regions (Schroeder et al., 2019).

Many analysts and market participants hypothesize there is a connection between the basis variability and thinning cash markets. However, it is difficult to isolate that impact, given that so many changes are taking place. The purpose of this study is to evaluate how thinning cash markets impact ability to predict live cattle basis, while accounting for changes in market fundamentals and price momentum. Additionally, we consider how the impacts vary regionally. Identifying and measuring these impacts will provide insights into basis predictability and how structural changes in the live cattle industry have impacted risk management potential of futures contracts.

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 may have decreased hedging effectiveness (Schroeder et al., 2019). When unexpected changes in factors lead to basis variability, this generates uncertainty for all livestock market participants. Cattle feeders, beef packers/processors, and market analysts may need to adjust and evaluate their business, marketing, hedging, and risk management strategies.

The CME Group live cattle futures contract is the primary price risk management tool for all the parties in US cattle markets looking for protection against adverse price changes (Schroeder et al., 2019). 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.

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) considered high-frequency trading as a possible cause of the variability in fed cattle markets, but their findings suggest that fundamentals were driving 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, and live cattle market participants' composition. They also noted there have been changing fed cattle marketing methods a trend towards higher quality beef. These changes may account for regional price differences.

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. Commonly, basis risk varied across geographic locations and has a seasonal component because each local market has specific characteristics and conditions. Overall, basis risk increased in 2014–2016 relative to historical records (Figure 1 and 2). Wilder et al. (2018) identified that the basis variance for the 2014-2017 period was larger than the basis variance during the 2004-2013 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 declining in 2017. The heightened basis variation can reduce the hedging effectiveness of CME Group live cattle futures contract. Understanding how and why basis risk is changing over time and across regions is helpful for hedgers in order to improve the risk management by hedging with future contracts.

Numerous empirical studies about basis in live cattle markets have been conducted, and most emphasize price relationship, hedging, and/or basis predictability. These studies use aggregate price data (weekly and monthly data series) to estimate hedonic models to forecast or explain live cattle basis in order to predict a most accurate basis when future contracts expired (Coffey et al., 2018; Liu et al., 1994; Naik & Leuthold, 1988; Parcell et al., 2000; Tonsor et al., 2004). Often, 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). Coffey et al. (2018) analyzed basis prediction errors across the live cattle five major Livestock Mandatory Price Reporting (LMR) regions . 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.

Methodology

Conceptual and Empirical Model

Hedging effectiveness can be measured using Basis Prediction Error (BPE), which is the difference between the actual and expected basis. Expected basis is often determined by historical cash and futures prices. In this case, BPE can be conceptually 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 market conditions for a given week (z) (Liu et al., 1994). Then, BPE can be defined, empirically, as:

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

Where ε is a random error when the other variables remain unchanged.

This study estimates how the changes in economic factors are related to the variability of a weekly basis (the difference between cash and futures prices) for three major live cattle

production regions. The purpose of this study is to examine how the changes of different economic variables impact the hedging error, which is a different approach from many previous studies, which evaluated the best way to forecast and explain the basis.
We used concepts and methods similar to 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. In practice, basis is calculated and reported in absolute terms as shown in Figure 1. However, it can also be represented as a ratio of cash to futures (Coffey et al., 2018; Liu et al., 1994). There are trade-offs to this approach where the basis is the cash price as a percentage of nearby futures prices (Figure 1). Basis reported as a ratio, or percentage, will not be as familiar to hedging practitioners. However, comparing a percentage basis might be more appropriate over a long period of time when the price levels differ drastically. A limitation when estimating the basis as a proportion is that some basis components, such as delivery cost, are likely absolute but others, such as shrink, are relative to the price. Calculating basis as a proportion might obscure the effects of some components. Considering the advantages and disadvantages, we opt to follow the precedent of Liu et al. (1994) and (Coffey et al., 2018) and calculate basis as a proportion.

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 moving average beginning in June 2004. Basis and expected basis are in percentage; hence, the BPE is expressed in percentage points:

$$BPE_{y,w} = Basis_{y,w} - \left(\frac{\sum_{y-3}^{y-1} Basis_{y,w}}{3}\right) \quad (2)$$

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 a measure of hedging accuracy, which indicates how close the expected basis estimated was to the actual basis. It could be positive if the actual basis is stronger than expected or negative if the actual basis is weaker than expected. Figure 2 depicts BPE 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 future contract clears. In contrast, a BPE of -5% indicates that the expected basis was 5% below the observed basis when the future contract clears. The sign of the BPE does not indicate that is bad or good because that will depend if the hedgers have a short or long position. For instance, a producer (with a short position) will benefit from positive BPE since the basis will be stronger indicating that the cash prices are higher than the futures prices, however, a beef packer (with a long position) will benefit from negative BPE. BPE only indicates the distance between the actual Basis and the Expected Basis.

Changes in Market Fundamentals

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 (equation 2), where the change is represented as a percentage change relative to the values expected based on historical data.

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

Where ΔX represents proportional changes in explanatory variables, y is the year, w is the week, and r is the region. We consider five variables to represent shifts in market fundamentals: Δ*HEAD*, Δ*NEGSHARE*, Δ*WEIGHT*, Δ*CSSPREAD,* and Δ*WAGES.* These are described in the next section and summarized in Table 1.

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. Similarly, the 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 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.

The variables Δ*CSSPREAD* and Δ*WAGES* were calculated using national data level. The Choice-Select Spread variable (Δ*CSSPREAD*) is a measure of what the market is willing to pay for Choice versus Select beef. 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 cut-out 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 future contracts as to the par percentage of cattle grading Choice. The contract specification changes could have altered basis. 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 last three years average.

Current Market Conditions

The model also includes two variables to represent current market conditions. First, *CORNRATIO* is price of live cattle divided by price of corn in a given region. The ration is directly interpreted as bushels of corn equal to one cwt of live cattle in terms of the total value and is a 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 analysts. We measure it contemporaneously, as shown in equation 4.

$$(4) \qquad CORNRATIO = \frac{\text{Live cattle local price}}{\text{Corn local price}}$$

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. 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 the magnitude of recent price movements are important to hedgers, considering that we are also accounting for many market fundamentals. *K* is bound between 0 and 100. The stochastic oscillator is calculated as

$$(5) \qquad K = \left(\frac{FP_{current} - FP_{lowest}}{FP_{highest} - FP_{lowest}}\right) * 100$$

Where the numerator, $FP_{current}$ is the current weekly nearby future 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.

CME live cattle futures contracts are offered for six different expiration months, in even calendar months. 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 6.

$$(6) \quad BPE_{w,y,r} = \beta_0 + \beta_1 \Delta HEAD_{w,y,r} + \beta_2 \Delta WEIGHT_{w,y,r} + \beta_3 \Delta NEGSHARE_{w,y,r} + \beta_4 \Delta CSSPREAD_{w,y,r} + \beta_5 \Delta WAGE_{w,y} + \beta_6 \Delta CORNRATIO_{w,y,r} + \beta_7 K_{w,y} + \beta_8 APRIL + \beta_9 JUNE + \beta_{10} AUG + \beta_{11} OCT + \beta_{12} DEC + \varepsilon_{y,w,r} \forall r.$$

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.

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 future contract specifications Choice/Select percentage requirements have changed. In order to analyze if the changes could influence BPE or not, a second model is estimated and includes 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.

A second model was estimated using all the previous variables described and including two more binary variables to represent the changes in the CME futures contracts specifications. The contract quality specification changes in recent years are described in Table 2. The CME future contract specified a par requirement of 55% Choice and 45% Select of the live cattle delivery from 2002 (and before) until October of 2017. 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). 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.

Monetary Impact of Explanatory Variables Shocks

We follow the procedure of Marsh (2001) to quantify impacts on BPE of one-standard deviation shocks to the explanatory variables. A one-standard deviation move is a realistic approximation for volatility in explanatory variables. Following this method, in the model estimated, the dependent and independent variables are expressed in terms of percentage and coefficients interpreted accordingly. Calculated the estimated impact of a shock to each right hand side variable allows us to report the impact of market changes on BPE in terms of dollars per cwt. This is more intuitive and instructive for practitioners. The calculation consists of multiplying the coefficient of each variable by its own the standard deviation and a future price. The result is divided by one hundred to convert the coefficient estimate from percent. The formula is shown in equation 7.

$$(7) \quad Impact\ in\ BPE = \beta_i * \frac{Future\ Price}{100} * SD.$$

Where Impact on *BPE* is expressed in ($/cwt), β_i is the coefficient of the variable estimated in the GLS model, SD is the standard deviation of the data series of each variable used to estimate the model. The variables *CORNRATIO and K* are current market measures; therefore their respective coefficients were not divided by 100.

To select the price level at which we want to evaluate the volatility of each variable, we estimate the mean of the nearby live cattle futures contract price over 2004–2019, which is 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 when the other variables remain constant (ceteris paribus). This analysis does not consider the probability of the shock.

Data and Estimation

The data used for this study are from the Livestock Mandatory Price Reporting (LMR) data collected by the USDA Agricultural Marketing Service (AMS) and archived 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. This period analyzed it was selected based on the data available at the regional data level to estimate the changes in the variables. We consider three of the five major regions reported by LMR: Kansas, Nebraska, and Iowa-Minnesota[3]. For the missing data in the weekly data series, the monthly average values used to approximate the value of that specific week. However, less than 1% of the data were filled using this method.

The data series of all the variables were arranged by calendar week, having 52 weeks per year and each week ending on Friday. The live cattle cash prices were collected at the regional level (KS, NE, IA-MN). These were weighted average of live FOB steer and heifer prices. Cattle weights were the weighted average of carcass weights of all steers and heifers, FOB and delivered sales in a week.[4] Live cattle negotiated market share was defined as all steers and heifers sold via negotiation, as a proportion of all live cattle marketings in a region for a given week. Local corn prices were state-level averages collected from USDA AMS. Futures price data, choice-select spread, total live cattle marketed, and wages were collected at the national level and do not vary by region. 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.

The BPE data series were stationary according to the Augmented Dickey-Fuller tests. Commonly in this type of studies, there are autocorrelation in the errors and overlapping data problems because data series used to estimate the current values can be correlated with previous

[3] The weekly negotiated steer and heifer price series for Texas and Colorado are missing over half the prices in 2018 and 2019. We opted to remove those from the analysis rather that replace such a large portion of prices.
[4] The weighted average weight of live cattle was calculate using live and dressed cattle categories, and dressed weights were converted to live weights considering 63% dressing percentage.

periods (e.g., Coffey et al. (2018); Tonsor et al. (2004)). Given those conditions the following process were done in order to approach and correct the econometric problems. First, regional OLS models were estimated (Equation 6), and the Durbin Watson Test used to check autocorrelation in errors. The results showed presence of first-order autocorrelation in the errors (Table 4). For the second part of this process Generalized Least Squares (GLS) models were estimated using Restricted Maximum Likelihood (REML) approach and specifying a correlation structure ARMA (1,1) to reduce the autocorrelation[5] in the errors and the overlapping data problems. The GLS models were tested with the Durbin Watson Statistic, and the results indicated that the autocorrelation had been removed. The ACF graph shows a decreasing trend on the effects of the errors and is not present after ten lags.

Results and Discussion

Regional GLS models were specified as shown in Equation 6. Each model was estimated using 654 observations (weeks) starting from June 2007 to December 2019. Results are shown in Table 5. The following section discusses estimation results in terms of significance, direct impact, and magnitude by region. In the second part of the discussion, an analysis of the monetary impact of volatility in the right hand side variable on *BPE* is described.

The interpretation of individual coefficients is the percentage point change in *BPE* given a one percentage point change in a given variable, *ceteris paribus*. This data specification is consistent with the concept that, if the market conditions in a specific week are similar to the market conditions from the three previous years, then the *BPE* should be smaller. If current conditions differ from previous years, the magnitude of *BPE* will increase. The impact of Δ*HEADS* on *BPE* was statistically significant and has a positive relationship in the three regional models. This implies that when more cattle are being traded across markets than expected, there is a stronger basis and the *BPE* is more positive. The results correspond with the findings of Coffey et al. (2018), who reported a similar result for Nebraska and Iowa when hedging. However, he found no such relationship in Colorado, Kansas, or Texas. Interpreting this relationship is difficult due to the simultaneity of the cattle feeder situation. A larger supply of live cattle should depress the price. However, elevated prices in a given week would give incentive for feeders to sell more cattle. In this analysis, it is impossible to determine causality.

The Δ*NEGSHARE* variable was statically significant for the three regions evaluated and has a positive impact on *BPE.* and has the smallest impact in IA-MN. This variable represents the negotiated market's relative thinness compared total number of live cattle marketed in the region. This suggests that if the spot market is thicker than previous years, *BPE* will be more positive, which is a consequence of a stronger than expected basis. Hedgers with a short position would benefit from those positive errors in the predictions, as this would lead to higher than expected net prices received. Coffey et al. (2018) found similar results showing that the Negotiated Marketed Share has a statistically significant and positive relationship with *BPE* in regions of KS, NE, TX, IA-MN, and CO. Wilder (2019), using the OLS estimation method, identifies that

[5] The R package named NMLE was used to perform the function "auto.arima" to know the correlation structure of the errors and according to this function the structure that is better to correct the econometric problems is ARMA(1,1).

the variable the percentage of the negotiated cash at the regional level has a significant and negative impact on basis after January 2014. However, this same variable also shows significant and a positive effect on the basis in the region of Kansas in years prior 2014. These results indicate that thinness of negotiated markets matters regarding 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* and that short hedgers fair better in such a market.

Changes in the Average Weekly Weight of the live cattle sold (Δ*WEIGHT)* showed a statically significant negative relationship with *BPE* for Kansas, Nebraska, and Iowa-Minnesota. The Δ*WEIGHT* variable indicates when the cattle sold are heavier or not than the average weight expected. 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) found a negative and statistically significant impact of increasing weights on *BPE*. In Kansas, Texas, and Colorado. Parcell et al. (2000) found that the average marketing weight was not statistically significant for any of the basis models for the regions of Kansas, Colorado, and Texas. The results imply that when heavier cattle are sold in the market, the *BPE* is more negative, which is a consequence of a weaker basis. Negative errors when forecasting will benefit long hedgers because that suggests that future prices are higher than cash prices.

The relationship between Choice Select Spread (Δ*CSSPREAD)* and *BPE* was statistically significant for the regional model of Iowa-Minnesota. A wider than expected spread corresponds with a more positive BPE. For the regions of Kansas and Nebraska, the effect of Δ*CSSPREAD* is not statistically different from zero. The Δ*CSSPREAD* measures 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 the 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 and gives the opportunity to make some changes to the feeder program in order to achieve better beef quality grades. This implies that there are more positive *BPE* when there are more slaughter cattle with high quality available in the market. Parcell et al. (2000) found using monthly data from 1990 to 1997 that changes in the Choice Select Spread are statistically significant, having a positive relationship with the basis for 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. 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, and this variable increased in significance post-2013.

The coefficient on delivery cost (Δ*WAGES*) was statistically significant in the three regional models and had a negative relationship with *BPE*. This indicates that if the wages of the truck drivers increases, relative to past years, this will correspond with a more negative *BPE*. Our results support the findings of Coffey et al. (2018), who found that changes in delivery cost had a significant and negative relationship with basis prediction errors. Similar results obtained 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 note that feeder cattle are more likely to be hauled long distances, so diesel fuel is more important in this case.

CORNRATIO and *K* are variables measured using current values and not in changes as the previous variables analyzed. *CORNRATIO* relationship with BPE was statistically different from zero and positive for KS, NE, and IA-MN. The magnitude of the coefficient for KS is bigger than for the other two regions. *CORNRATIO* can be interpreted as the marginal benefit of adding pounds to live cattle. This variable is a proportion not converted to percentage terms. The ratio can increase in two ways: 1) when the corn price falls or 2) when the local cattle cash price increases. When either of these conditions happens, the *BPE* becomes more positive since basis is stronger than expected. Previous studies 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 corresponded to a decrease in live cattle basis for KS, TX, and CO. 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, processors or beef packers could increase their bids to incentivize the fed cattle producer to sell their cattle. The results of these decisions from the supply or demand side impact directly in the local cash prices and basis prediction error could increase or decrease.

Shifts in the stochastic oscillator (*K*) are statistically related to *BPE* in KS and NE but direction differs by location. In KS, the relationship is negative and positive in NE. Coffey et al. (2018) found the statistical significance of the coefficients on the Stochastic Oscillator, revealing that positive price 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. His results indicated a statistically significant and negative relationship between basis and RSI. RSI and stochastic oscillator are both commonly used measures of market price momentum in investing and technical analysis. These findings suggest that price momentum impacts hedging effectiveness.

The models include binary variables representing future 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 NE model where the future contracts expiring in June is significant at 1%. For this case, finding no consistent statistical differences

across contract options is reassuring. This result suggests all the futures contracts available perform equally well for hedging prices across the year and regions.
Comparing the results of our first (equation 6) and second model, which include the changes in the contract specifications as described in the empirical framework, estimates are generally consistent with the initial models. The major difference is that the coefficient on Δ*CSSPREAD,* is statistically significant and positive across the three regions evaluated. We find that the two specification changes, *CHOICE60* and *CHOICE65*, correspond with statistically significant and negative changes in KS and NE, but this relationship is not significant for IO-MN region. The negative relationship between the specification changes and BPE indicate that local basis was weaker than expected after the specification changes. That finding is to be expected since the changes increased the required percentage of cattle grading choice, which should raise futures price, all else equal. One would not expect physical cattle to change dramatically during this time period, so a weaker basis is the result. There is also the practical limitation of comparing an expected basis based on outdated contract specifications. Due to this, the small number of observations under the new specifications, we caution drawing too many inferences from these findings but note that, in terms of direction, impacts are consistent with expectations.

Monetary Impact of Explanatory Variables Shocks

Unexpected shifts in market fundamental conditions and price momentum show impacts on hedging effectiveness. We evaluate a one standard deviation positive change to each explanatory variable, while the other variables remain constant. Using the parameter estimates from the initial model, we calculate the predicted change in *BPE* from this shock. We then convert the change in *BPE* to a change in net price received by multiplying by futures price. We use a live cattle futures price of $110. This value is approximately the average of the live cattle price from 2007 to 2019. Overall the results indicate that Kansas is more sensitive to changes in *CORNRATIO*, Nebraska is more affected by changes in *WAGES*, and the changes in *CSSPREAD* has more impact Iowa-Minnesota region. The variables Δ*WEIGHT*, Δ*NEGSHARE*, Δ*WAGE*, and *CORNRATIO* showed a consistent effect across regions. However, the variables ΔHEAD, Δ*CSSPREAD* and *K* display different effects according to the region. The magnitude impact of 1-SD increases varies across regions, as depicts in Figure 3.

When the number of head of live cattle traded (Δ*HEAD*) increase 1-SD show that has a downward effect over *BPE* for KS and NE but upward for IO-MN. The larger impact is shown in KS decreasing by $0.98/cwt suggesting is most sensitive to changes in the number of live cattle marketed across the four transaction types markets. For NE decreases by $0.56/cwt and for IO-MN increases by $0.30/cwt with the same change. The increase of 1-SD on the variable Choice Select Spread (Δ*CSSPREAD*) has a negative effect over *BPE* for KS and NE, but a positive effect for IA-MN also shows been more sensitive to 1-SD shock, having a net price increment of $0.80/cwt when the Δ*CSSPREAD* increase by 2.9%. Parcell et al. (2000) found that a $1/cwt increase in the Choice Select price spread for 700 to 850 pound boxed beef cut-out equivalent strengthened basis by approximately $0.12/cwt in each of the regions. An increase of 1-SD over the freight cost (Δ*WAGES*) had a downward effect on *BPE*. The larger impact is shown in the NE decline by $0.70/cwt when the wages increase by 0.9%. Moreover, KS is $0.60/cwt, and for IA-MN declines by $0.50/cwt.

The variable *CORNRATIO* has a positive impact on *BPE*. The region more sensitive was Kansas, increasing $1.02/cwt in the net price. The Iowa-Minnesota region by $0.24/cwt and Nebraska by $0.14/cwt. The results from our models show consistency with the findings of these previous studies, given that they directly used the corn price as a variable in their model, and we used a ratio. 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.

When basis are more unpredictable, give as a consequence elevated basis prediction errors, which increase the risk around the prices. These errors in the forecasting basis could be detrimental or beneficial for hedgers depending on the positions on the market (long and short position). If the local cash prices are higher than the futures prices, the basis is stronger, and short hedgers increase their profits. In contrast, when local cash prices are lower than future prices, the basis is weaker, and long hedgers increase their profits. For instance, the results suggest that if the negotiated market share becomes thinner the *BPE* will increase when forecasting basis. For the short hedgers, this could be beneficial; however, for long hedgers could be detrimental; as explained before. Producers who usually have a short position in the future market, having a higher positive Basis Prediction Errors when forecasting basis will increase their profits as long as they hold a short position in the futures markets.

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. This study used regional models to estimate how the impact of changes in the market conditions affects the basis prediction error in weekly fed cattle basis for Kansas, Nebraska, and Iowa-Minnesota regions. The independent variables serve to represent the shifts in the market fundamentals. The results support the findings from previous studies, which state that live cattle basis predictability is affected by various economic factors, and any change in the market conditions impacts the net prices directly.

The results suggest that a positive change in factors such as the thinness of the negotiated market and cost of gain will increase the *BPE*. On the other side, a positive change in the variables such as the average weight per head of the live cattle marketed and delivery costs will decrease the *BPE*. The impact of the changes in factors such as total head of live cattle marketed, the current premium for high-quality beef, delivery costs, and the price momentum measures varies across regions. The model also includes contract binary variables and shows that overall all the futures contracts perform equally along the year and across regions.

Aggregate data analysis allows us to give son insights into the general trend, however, each market participant must take into count their current and specific conditions at the local market in order to give any conclusion on how to affect the changes in the market fundamentals and how those effects are incorporating in each local cash market that will be used to make the transaction. The constant changes in the market conditions influence the basis variability, and their impact differs across geographic regions and over time (Not all the regions react similarly to the same changes). Most of the factors analyzed showed power when explaining basis variability and hedging effectiveness, but the market participants should consider other factors with more potential explanation power or influence in a specific market and region.

The analysis of the monetary impact of explanatory variables shocks showed that changes in the costs of gains have a larger monetary impact on the basis for Kansas. The changes in delivery costs have a higher monetary impact on the basis for Nebraska. The Iowa-Minnesota region is more sensitive to changes in the current premium for high-quality beef. These factors could be the major drivers of the basis variability in each location and need to be considered when forecasting because they could be the main sources of the decreasing trend of hedging effectiveness.

During periods where the basis is more unpredictable and produces elevated basis prediction errors, which increase the risk around the prices, these errors in the forecasting basis could be detrimental or beneficial for hedgers depending on their position in the market (long and short position). Therefore, the *BPE* cannot be classified as good or bad, are only forecasting errors. The market conditions are changing quickly and constantly, all the live cattle market participants must consider updating their knowledge of the role of each market fundamental, and their possible effect on the final price received or when it is time to clear the hedging.

The method used to estimate basis and basis prediction errors in this research has trade-offs. In the cattle industry is common to estimate and report basis in absolute terms. However, it can also be represented as a ratio of cash to futures as done in this research. Basis reported as a ratio, or percentage, will not be as familiar to hedging practitioners. The current approach where the basis is estimated as the proportion cash price concerning the futures prices could be more appropriate across a long period, especially when the price levels are drastically different. This approach allows a comparison among the variables evaluated since it is in percentage values no matter in which type of measure is used in the industry, also, serves to control inflation over the years. Some components that affect basis variability are estimated in absolute terms such as delivery costs, and others are calculated in relative terms with respect to the price, such as shrink costs. These add one more layer to the complexity of identify the sources of basis variability given that the actual impact of some components could be amplified or obscured depending on the method used to estimate basis.

This analysis gives some insights into how the changes in major market fundamentals affect the basis predictability. Even though hedging errors have been increasing in recent years, this fact does not imply that futures contracts are not beneficial when hedging. Overall, the basis variability has increased and resulted in the decrease in hedging effectiveness in the live cattle markets, but hedgers are still better off using the futures contracts to manage risk as basis risk is substantially lower than price risk. This study updates the knowledge regarding the complex and constantly changing role of each market fundamental factor and serves as a guide to improve hedging effectiveness.

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Table 1. Description of variables used in 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).

Note: Δ% represent percentage change of the variable.

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

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

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

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 period from April 2007 to December 2020.

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	2.20	2.17	2.18

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.

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

	Units	KANSAS		NEBRASKA		IOWA-MN	
INTERCEPT		1.054	***	1.98	***	2.58	***
		-0.338		-0.468		-0.464	
Shifts in Market Conditions							
ΔHEAD	%	-0.052	***	-0.033	***	0.01	***
		(0.01)		(0.01)		(0.00)	
ΔWEIGHT	%	-0.272	***	-0.221	***	-0.133	***
		(0.03)		(0.05)		(0.02)	
ΔNEGSHARE	%	0.016	***	0.003		0.02	***
		(0.00)		(0.00)		(0.01)	
ΔCSSPREAD	%	-0.031		-0.021		0.249	***
		(0.02)		(0.03)		(0.03)	
ΔWAGE	%	-0.609	***	-0.704	***	-0.505	***
		(0.05)		(0.06)		(0.08)	
CORNRATIO	bu/cwt	0.104	***	0.024	***	0.014	*
		(0.01)		(0.01)		(0.01)	
K	%	-0.004	*	0.017	***	0.001	
		(0.00)		(0.00)		(0.00)	
Future Contract Binary variable							
APRIL		-0.174		0.521		0.161	
		(0.37)		(0.52)		(0.36)	
JUN		0.025		1.307	***	0.317	
		(0.30)		(0.41)		(0.32)	
AUG		0.157		0.567		0.295	
		(0.30)		(0.41)		(0.31)	
OCT		-0.456		-0.145		-0.206	
		(0.28)		(0.39)		(0.30)	
DEC		-0.084		0.341		-0.449	
		(0.37)		(0.51)		(0.35)	
N		654		654		654	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the REML approach and correlation structure of the errors ARMA (1,1). Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default binary variable. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5% and 1% levels, respectively.

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

	Units	KANSAS		NEBRASKA		IO-MN	
INTERCEPT		-2.172	***	1.386	**	2.076	***
		(0.78)		(0.60)		(0.61)	
Shifts in Market Conditions							
Δ HEAD		0.012	***	0.004		0.011	***
	%	(0.00)		(0.01)		(0.00)	
Δ WEIGHT		-0.115	***	-0.25	***	-0.126	***
	%	(0.03)		(0.05)		(0.02)	
Δ NEGSHARE		0.012	***	0.007	*	0.019	***
	%	(0.00)		(0.00)		(0.01)	
Δ CSSPREAD		0.124	***	0.148	***	0.278	***
	%	(0.04)		(0.03)		(0.03)	
Δ WAGE		0.214		-0.216	*	-0.384	***
	%	(0.14)		(0.12)		(0.12)	
CORNRATIO	bu/cwt	0.079	***	0.022	***	0.015	**
		(0.02)		(0.01)		(0.01)	
K	%	-0.002		0.003		0.001	
		(0.00)		(0.00)		(0.00)	
Future Contract Binary variable							
APRIL		-0.288		-0.028		0.127	
		(0.32)		(0.31)		(0.35)	
JUN		0.464		0.261		0.286	
		(0.37)		(0.30)		(0.32)	
AUG		0.483		-0.041		0.269	
		(0.36)		(0.28)		(0.30)	
OCT		0.156		-0.357		-0.236	
		(0.36)		(0.28)		(0.30)	
DEC		-0.203		-0.424		-0.473	
		(0.32)		(0.31)		(0.35)	
CSC6040		-1.44	***	-1	***	-0.3	
		(0.52)		(0.27)		(0.26)	
CSC6535		-3.174	***	-1.748	***	-0.505	
		(0.56)		(0.36)		(0.36)	
N		654		654		654	

Notes: Coefficient estimates, standard errors, and R-squared measures are from GLS estimation using the REML approach and correlation structure of the errors ARMA (1,1). Futures contract binary variables equal 1 when that particular contract is the nearby contract and 0 otherwise. The February contract is the default binary variable. Single and double asterisks (*, **, ***) indicate statistical significance at the 10%, 5% and 1% levels, respectively.

Figure 1. Weekly basis for the regions of Kansas, Nebraska, and Iowa-Minnesota (Basis estimated as percentage).

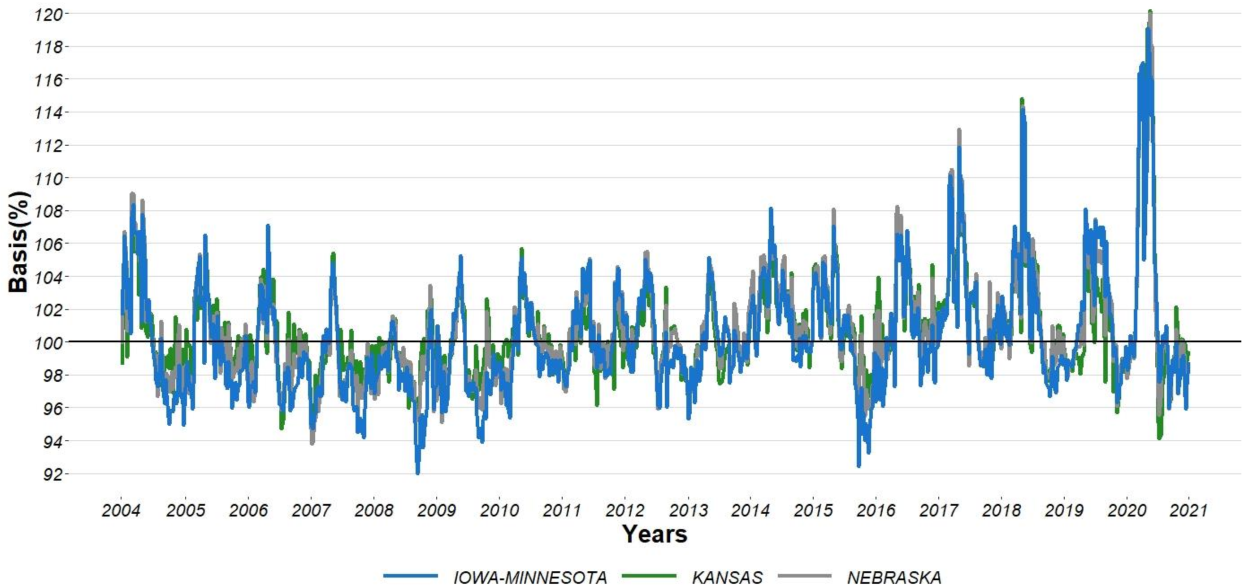

Figure 2. Basis prediction error at regional level (Kansas, Nebraska, Iowa-Minnesota).

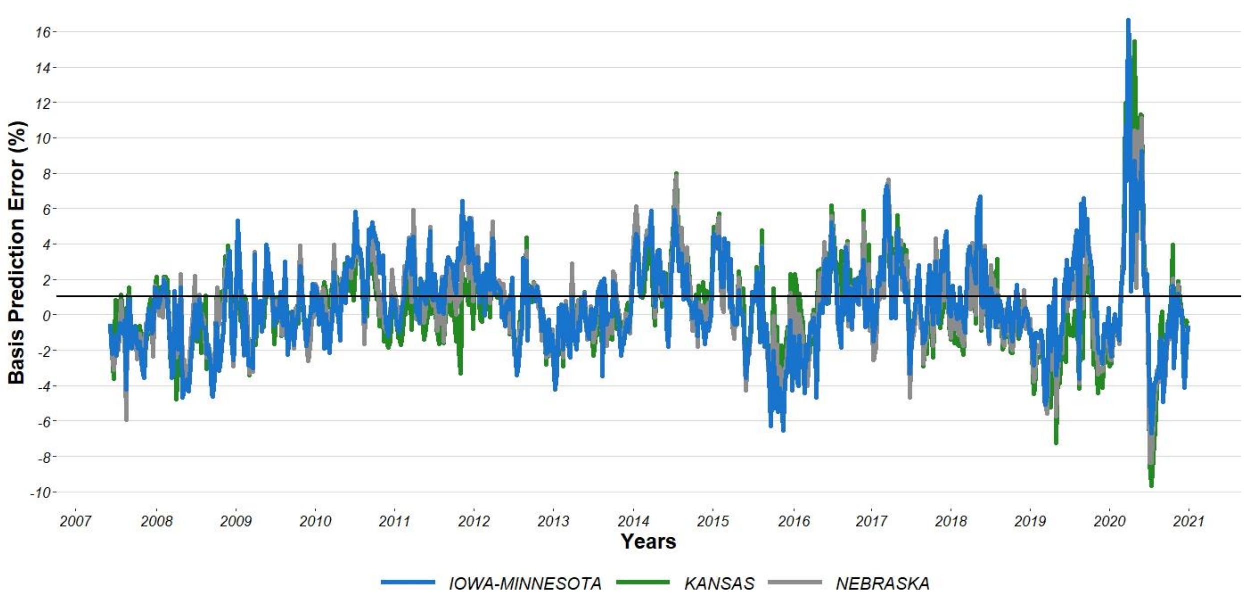

Figure 3. Estimated impacts on Basis Prediction Error in monetary terms when the economic variables increase by one standard deviation.