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Impacts of Changes in Market Fundamentals and Price Momentum on Hedging Live Cattle

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Basis prediction errors for live cattle in the five major Mandatory Livestock Price Reporting areas are analyzed to determine how shifts in the live cattle market fundamentals and contemporaneous market conditions, including price momentum, impact ability to hedge. Results reveal that thinness of the negotiated cash market, weight of cattle marketed, and contemporaneous factors statistically impact basis prediction errors. Impacts vary across region. Volatility in cost of gain and delivery costs have greater effects on basis prediction error than do market trends.

Key words: basis, CME Live Cattle Contract, risk management

Introduction

Live cattle markets are risky, and large fluctuations in prices dramatically affect market participants' profits. The Live Cattle Futures contract traded on the Chicago Mercantile Exchange (CME) is widely used to hedge live cattle cash price risk. Effective hedging requires that futures and cash price be related in such a way that nearby basis (cash price minus nearby contract futures price) is predictable (Purcell and Koontz, 1999; Garcia and Sanders, 1996). Market conditions over the past few years have raised concerns about whether the Live Cattle Futures contract continues to serve as an effective hedging instrument, in part because of unprecedented basis variation (National Cattlemen's Beef Association, 2016).

In 2014, live cattle cash prices climbed to record highs, followed by a rapid decline in 2015 and 2016. During this period of price decline, cattle hedgers realized nearby basis levels that differed substantially from previous years. Figure 1 shows the weekly basis from June 2004 to June 2016 between the price of Kansas steers sold via negotiation in the cash market and nearby CME Live Cattle Futures contract price. Weekly live cattle basis from 2014 to 2016 had uncommonly large levels of magnitude and week-to-week variation relative to historical basis. Additionally, seasonal patterns, which were somewhat predictable between 2005 and 2013, did not hold in the more recent years. Though not presented here, similar patterns are present in corresponding basis data for all major live cattle reporting regions. Using historical basis data to form future basis expectations in any of these regions—as is commonly done (Hatchett, Brorsen, and Anderson, 2010)—resulted in substantial errors in basis predictions. Elevated basis prediction errors directly translate into increased risk to hedgers.

This study quantifies the impacts of changes in fundamental economic factors and price trends on live cattle basis predictability. Basis prediction errors are modeled as a function of relevant economic variables to determine how shifts in the live cattle market and contemporaneous market conditions impact basis predictability. Explanatory variables include price momentum, which is used to measure patterns in price movement. The process is repeated for each of the five major Livestock Mandatory Price Reporting (LMR) regions for live cattle prices (Colorado, Iowa/Minnesota, Kansas,

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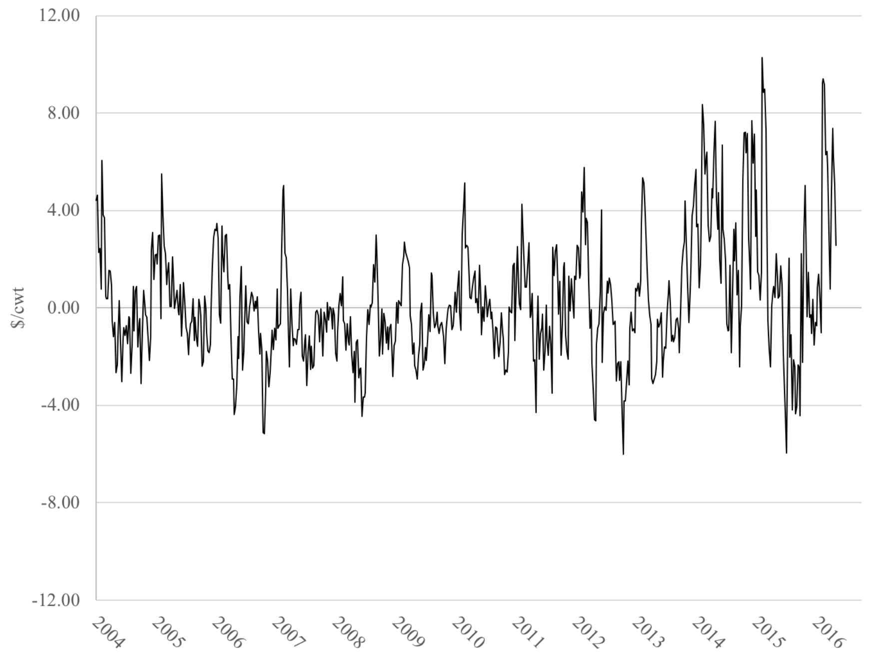

Figure 1. Weekly Nearby Basis: Kansas Live Steers – Nearby CME Live Cattle Futures, 2004–2016

Notes: Futures prices are CRB weekly averages of the nearby CME Live Cattle Contract, cash prices taken from LMIC data based on livestock mandatory price reporting data from the USDA Agricultural Marketing Service.

Nebraska, Texas/Oklahoma/New Mexico). Results reveal that both changes in market conditions and contemporaneous factors statistically impact basis prediction errors. Price momentum has a statistically significant relationship with basis prediction error. Across all market regions, the relative magnitude of changes in basis prediction error due to volatility of price momentum is less than impacts due to volatility of delivery costs and net benefit of adding pounds to cattle.

Previous Literature

The relationship between futures and cash prices (i.e., basis) has been examined in the agricultural economics literature in a multitude of contexts. The current understanding of basis for storable commodities is largely built upon the seminal efforts of Working (1948, 1949, 1953). However, the same concepts do not necessarily apply for nonstorable or semistorable commodities such as live cattle (Naik and Leuthold, 1988). Early research in this area hypothesized that live cattle basis is a result of shifting supply and demand conditions (Leuthold, 1979). The importance of supply shifts on changes in live cattle basis was empirically confirmed by Leuthold (1979) and Tomek (1980). This body of research indicates that, though lacking the direct functional relationships of storables, live cattle cash and futures prices should converge in a predictable way at maturity (Garcia and Leuthold, 2004).

Garcia, Leuthold, and Sarhan (1984) modeled variability in live cattle (and live hog) basis and concluded that variables representing long-term price levels and unexpected price change influence basis risk. Empirical research by Naik and Leuthold (1988) decomposed live cattle basis into a speculative component and a maturity component. Further efforts to explain live cattle basis and basis variability revealed that corn prices impact basis, as do market fundamentals and seasonal components (Parcell, Schroeder, and Dhuyvetter, 2000). More recent literature has turned attention to forecastability of nearby basis. Liu et al. (1994) found that futures market information, such as open interest and lagged spread between current and two-month deferred contracts, has more predictive power than do supply and demand factors. However, supply and demand factors contribute unique information to the forecast. Delivery costs, modeled using consumer price index (CPI) as a proxy, were also a significant factor in predicting basis (Liu et al., 1994; Garcia, Leuthold, and Sarhan, 1984). Tonsor, Dhuyvetter, and Mintert (2004) compared different lengths of moving-average forecasts of live cattle basis and concluded that including current market information can improve forecast accuracy. Taken as a whole, existing research specifically focused on live cattle basis indicates that live cattle basis is difficult to accurately forecast or explain and that results vary depending on time period and location, among other factors. For example, lagged basis contains significant explanatory information (Naik and Leuthold, 1988; Liu et al., 1994) but, in a more recent study, the finding does not hold in every local market (Parcell, Schroeder, and Dhuyvetter, 2000). Both long-term variables and short-term dynamics influence live cattle basis (Liu et al., 1994; Garcia, Leuthold, and Sarhan, 1984).

Conceptual Framework

A pure hedging strategy is one that seeks to manage price risk. Therefore, an effective hedging strategy allows a hedger to realize a net cash price equal to expected cash price, regardless of price level. Hedgers use futures price at the time the hedge is set plus expected basis at the time the hedge is to be lifted to arrive at expected cash price (Purcell and Koontz, 1999). A perfect hedge is one where actual net price received equals expected cash price. The difference between expected and actual cash price is hedging error and is simply the magnitude by which the hedger's basis prediction differs from actual basis when the hedge is lifted. In other words, hedging error is defined by basis prediction error (*BPE*), which is the difference between actual and expected basis.

As mentioned previously, empirical analysis has found live cattle basis to be a function of local supply and demand factors (Liu et al., 1994; Parcell, Schroeder, and Dhuyvetter, 2000) and short-term dynamics (Liu et al., 1994), implying that current economic information is embedded in local basis in a given time period. Further, if expected basis prediction is based on past market data, lagged economic information is contained in the expected basis. To the extent that levels of all lagged factors are consistent with their current levels, *BPE* should approach 0. In other words, expected basis will be a better predictor if current supply and demand fundamentals are similar to those upon which predicted basis is based. *BPE* would then be a function of how current variables determining the live cattle market have changed relative to the level of those variables inherent in the expected basis prediction (Δx) and a set of variables defining contemporaneous, idiosyncratic market conditions of the current week (z). The variables in z measure period-specific economic factors such as price of inputs and short-term market conditions and are defined by their level in the current week and year. Both of these sets of variables affect cash and futures price of live cattle such that *BPE* can be defined as

$$BPE = f(\Delta x, z). \tag{1}$$

Empirical Framework

Based on the preceding conceptual framework, *BPE* can be estimated as

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

where ε is a random error term and other terms maintain their previous definitions. Variables in Δx and z are not directly observable. Based on data availability, reasonable proxies must be identified. We follow knowledge gained from previous efforts to model live cattle basis (Naik and Leuthold, 1988; Newsome et al., 2004; Parcell, Schroeder, and Dhuyvetter, 2000; Liu et al., 1994) and current live cattle market issues (National Cattlemen's Beef Association, 2016) to specify the empirical model.

BPE depends upon the way in which expected basis is determined. Given that ease of application is important (Parcell, Schroeder, and Dhuyvetter, 2000) and that more complex models involve high transaction costs (Liu et al., 1994), taking a simple average of historical basis observations is one of the most common methods. A survey of livestock extension websites confirmed that a three-year average of live cattle basis is often reported to give producers a basis forecast for the upcoming production year (e.g. Kansas State University AgManager, 2016; Iowa State University Ag Decision Maker, 2016). For weekly basis, this requires taking an average of the same week across the previous three years. Hedgers and analysts may identify corresponding weeks from years using calendar weeks or weeks to contract expiration. Tonsor, Dhuyvetter, and Mintert (2004) found that, in terms of impact on hedging errors, the two methods are statistically similar. Considering these circumstances, we assume expected basis is determined using an average basis of the previous three years in the particular calendar week during which the hedge is to be lifted. Given that nominal price levels have varied dramatically during the time period analyzed, we defined regional basis in percentage terms. Specifically, basis was calculated as local cash price divided by nearby futures price and multiplied by 100 to convert to a percentage of nearby futures price. This method of defining basis controls for inflation and extreme price levels and has been used in studies focused on live cattle basis (Liu et al., 1994) and grains (Etienne, Mallory, and Irwin, 2017; Mallory, Zhao, and Irwin, 2015). As basis and expected basis are defined in terms of percentage of nearby futures, it follows that *BPE* (the difference between the two) is also in percentage of nearby futures price. *BPE* was calculated as

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

where $BPE_{y,w}$ is the basis prediction error for calendar week w in year y and $Basis_{y,w}$ is the observed basis in a given calendar week and year. The average of $Basis_{y,w}$ over the previous three years (the term in parentheses) is expected basis.

Another method for arriving at an expected basis could be used. For example, one might forecast basis using an econometric model. In this case, the relationship between shifts in economic factors and *BPE* would not be as intuitive. However, the econometric model would be estimated using historic data and, therefore, *BPE* would still be sensitive to current market conditions that differ from the historical data used in the estimation. Further, the purpose of this study is not to identify the best forecast for basis but to examine how different economic variables impact *BPE* (and hedging error), given that a hedger consistently applied the same approach. Given the prevalence of the three-year average basis as a forecast, defining expected basis as such reflects measures for *BPE* similar to those experienced by feeders with an ongoing strategy to hedge at placement or packers hedging cattle purchases.

Changes in variables contained in x represent shifts in factors such as how live cattle are marketed and delivery costs and are calculated similarly to *BPE*, such that the change is represented as a percentage change relative to the average the measure in the same calendar week over the past three years:

$$\Delta x_{y,w} = \frac{x_{y,w} - \left(\frac{\sum_{y-3}^{y-1} x_{y,w}}{3} \right)}{\frac{\sum_{y-3}^{y-1} x_{y,w}}{3}} \times 100. \tag{4}$$

The set of variables in Δx represents changes in the live cattle market. Specifically, we use equation (4) to calculate percentage changes in head of live cattle marketed ($\Delta AllHead$), weight of live cattle marketed ($\Delta Weight$), proportion of live cattle marketings that are negotiated ($\Delta NegShare$), and transportation cost ($\Delta Wages$). Three of these variables serve as proxies for supply changes: $\Delta AllHead$, $\Delta Weight$, and $\Delta NegShare$. $\Delta AllHead$ is a proxy for changes in the aggregate supply of cattle. Changes in $\Delta AllHead$ are changes in a current week's live cattle marketings compared to the three-year average of the same measure, in the same calendar week. A positive value indicates that the number of cattle being sold in a region is larger than the average number sold in the same week across the previous three years. If demand conditions are unchanged, then such a supply increase will depress prices and weaken basis, which translates to a negative impact on BPE. However, a positive value of $\Delta AllHead$ could also be a short-run supply response occurring as a result of relatively higher local cash prices. In this case, $\Delta AllHead$ would be positively correlated with BPE. Given the dynamics of this relationship, it is difficult to determine the expected directional impact.

The average weight of cattle sold in a week impacts local basis (Parcell, Schroeder, and Dhuyvetter, 2000). $\Delta Weight$ is the change in the average weight of live cattle marketed in a given week relative to the three-year moving average. In general, as weight increases, local supply is increasing and live cattle cash price decreases. A positive value of $\Delta Weight$ would indicate heavier than normal cattle for a calendar week and should be negatively related to BPE. $\Delta NegShare$ measures changes in proportion of all live cattle marketings that are negotiated sales. This proportion could increase or decrease independent of aggregate supply conditions and is a proxy for shifts in live cattle marketing toward or away from negotiated sales.[1] Defining $\Delta NegShare$ in this manner allows a distinction to be made between absolute market thinness associated with fewer cattle being available ($\Delta AllHead$) and relative thinness in the negotiated market due a smaller share of cattle being marketed as negotiated sales. If $\Delta NegShare$ has a statistically significant impact on BPE, this suggests that thinness of negotiated live cattle markets impacts ability to hedge.

The last variable to measure a market change is $\Delta Wages$, which is a proxy for delivery costs. Conversations with industry participants confirmed that transporting live cattle by truck often involves relatively short hauls. Therefore, the majority of transportation costs arise from trucking companies covering fixed costs of operating the truck and cost of the driver's time to be present for loading and unloading. With this in mind, we chose the average hourly earnings of employees in the trade, transportation, and utilities industry, as reported by the Bureau of Labor Statistics (2016). This wage approximates wages paid to truck drivers, which are a major component of delivery costs. As delivery costs increase, we expect cash bids for live cattle to decrease and basis to weaken.[2] This relationship indicates that $\Delta Wages$ is negatively related to BPE.

Two variables, *CornRatio* and K, were included to capture current market conditions. *CornRatio* can be directly interpreted as the bushels of corn equal to 1 hundredweight of live cattle in terms of total value. This ratio is a proxy for the marginal benefit feeders receive from adding a pound to live cattle before slaughter. *CornRatio* is measured contemporaneously and not in relation to its moving average. The rationale for this is that basis is influenced by the fact that cattle feeders have some flexibility on when to market live cattle and that flexibility affects basis (Naik and Leuthold, 1988). That is, they can feed more or fewer days, within a given window of time, based on current conditions. The marginal feeding decisions could very well deviate from original feeding plans and, therefore, be somewhat independent of feed ingredient pricing or hedging decisions made at the time cattle were placed on feed. The higher *CornRatio*, the more incentive feeders have to continue feeding cattle. In a situation where *CornRatio* is high, packers will have to increase cash bids to encourage feeders to sell. We expect *CornRatio* and BPE to be positively related.

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[1] The model was also specified using absolute numbers of negotiated and non-negotiated marketings. Results from this model specification are included in the appendix.

[2] Cash prices used here are free on board (FOB) prices, indicating that the buyer is responsible for cost of delivery.

The stochastic oscillator, K, is a standard price momentum measure of the nearby live cattle futures price and is calculated as

$$K = \left(\frac{Fut_{current} - Fut_{low}}{Fut_{high} - Fut_{low}} \right) \times 100. \tag{5}$$

The numerator of K equals the current weekly nearby futures ($Fut_{current}$) price minus the lowest low nearby futures (Fut_{low}) observed in the past 14 weeks. The denominator is the highest high nearby futures price observed in the last 14 weeks (Fut_{high}) minus the lowest low observed during the same time (Fut_{low}). K is the ratio (bound between 0 and 100) of the distance of the current price from the lowest low to the range in which the contract has recently traded.

Price momentum is used widely in trading futures contracts as a technical indicator. There are varying opinions regarding what momentum measures capture and whether the implicit assumption that past prices impact future prices is appropriate (Erb and Harvey, 2006). In the context of this study, K is a reasonable proxy for market trends (e.g., price momentum is seen by some as an artifact of market participant behavior, Barberis, Shleifer, and Vishny, 1998) beyond those explained by the fundamental measures included in the model.[3] An increase in K indicates buying pressure in the futures market. As K approaches 100, the market is termed more "overbought" by traders, meaning that price level in the current period may be high relative to the recent range of trading for the contract. As K approaches 0, a market is said to be "oversold," implying the current period bids are low relative to recent trading range. The impact of K on BPE will depend upon the relationship between live cattle cash and futures prices. If the current week's futures price is high relative to the trading range of the past 14 weeks (i.e., K is relatively large) futures prices have an upward momentum. If increases in futures outpace increases in the cash market price, BPE will be more negative. If, on the other hand, cash prices outpace futures in the upward move, BPE will be more positive. The sign and significance of the impact of K will indicate whether, when controlling for fundamental forces, BPE is affected by price trends in the Live Cattle Futures contract.

Finally, binary variables were included to indicate which contract was the nearby for every BPE observation in each of the five regional models. Live cattle supply and demand conditions vary seasonally and, therefore, contracts expiring in different months could perform differently. It is also possible that, due to seasonal patterns in local live cattle supply and demand, a given contract might not function the same across all regions. Therefore, a significant coefficient on any of the binary contract variables would indicate a bias in performance of a given contract in a region.

The complete empirical model is specified as

$$\begin{aligned} BPE_{y,w,r} \quad = \quad & \beta_0 + \beta_1 \Delta AllHead_{y,w,r} + \beta_2 \Delta NegShare_{y,w,r} + \beta_3 \Delta Weight_{y,w,r} \\ & + \beta_4 \Delta Wages_{y,w} + \beta_5 CornRatio_{y,w,r} + \beta_6 K_{y,w} + \beta_7 Feb_{y,w} \\ & + \beta_8 April_{y,w} + \beta_9 Aug_{y,w} + \beta_{10} Oct_{y,w} + \beta_{11} Dec_{y,w} + \varepsilon_{y,w,r} \ \forall\ r. \end{aligned} \tag{6}$$

where indices y and w represent year and calendar week, respectively. Calendar week can take a value of 1 to 52 in each year. Index r is Livestock Mandatory Price Reporting region and varies over the major reporting regions of Colorado (CO), Iowa/Minnesota (IA), Kansas (KS), Nebraska (NE), and Texas/Oklahoma/New Mexico (TX). Following Parcell, Schroeder, and Dhuyvetter (2000), we specify a separate model for each region.

$BPE_{y,w}$ is the difference between observed basis in a given week and the average basis over the past three years during that same week. When $BPE_{y,w}$ is positive (negative), local basis is stronger (weaker) than historical data would predict. A positive (negative) estimate for a β coefficient would suggest that an increase of the variable in question corresponds with a strengthening (weakening) of local basis relative to expected basis.

[3] Price (and return) momentum is widely discussed in trading circles and used to develop trading strategies for commodity futures (Chaves and Viswanathan, 2016; Erb and Harvey, 2006). However, we know of no previous efforts to use it as an explanatory variable in a study analyzing livestock basis.

Table 1. Descriptive Statistics of Weekly Data, 2004–2016

Region	Variable	Units	Mean	St Dev	Min	Max	*N*
CO	*BPE*	% nearby futures	0.44	2.13	−7.19	7.52	474
	Δ*AllHead*	%	−2.28	21.89	−56.75	89.67	474
	Δ*NegShare*	%	−8.11	9.77	−42.83	19.64	474
	Δ*Weight*	%	1.53	3.24	−8.36	14.30	474
	CornRatio	bu/cwt	28.74	10.03	13.50	51.29	632
IA	*BPE*	% nearby futures	0.30	2.30	−7.09	6.30	474
	Δ*AllHead*	%	5.86	25.48	−55.33	111.85	474
	Δ*NegShare*	%	−4.08	11.53	−42.45	26.85	474
	Δ*Weight*	%	1.61	2.25	−24.93	10.27	474
	CornRatio	bu/cwt	30.74	11.93	13.95	59.63	632
KS	*BPE*	% nearby futures	0.27	1.91	−5.41	8.24	474
	Δ*AllHead*	%	−4.17	14.09	−36.66	40.11	474
	Δ*NegShare*	%	−6.50	9.96	−33.80	22.56	474
	Δ*Weight*	%	1.76	2.39	−3.47	9.63	474
	CornRatio	bu/cwt	28.88	10.15	13.44	50.98	630
NE	*BPE*	% nearby futures	0.39	2.10	−7.71	7.10	474
	Δ*AllHead*	%	0.19	16.30	−42.23	84.07	474
	Δ*NegShare*	%	−7.72	9.87	−38.65	31.77	474
	Δ*Weight*	%	1.81	1.58	−2.34	7.61	474
	CornRatio	bu/cwt	29.88	11.68	13.51	59.46	632
TX	*BPE*	% nearby futures	0.26	1.89	−4.68	7.10	474
	Δ*AllHead*	%	−3.76	15.07	−39.54	59.55	474
	Δ*NegShare*	%	−9.31	6.93	−43.03	6.39	474
	Δ*Weight*	%	1.22	3.37	−7.51	18.31	471
	CornRatio	bu/cwt	26.82	8.79	13.07	45.35	632
	K	%	54.70	33.45	1.61	98.59	635
	Δ*Wages*	%	4.42	0.66	2.96	5.77	477

Notes: Δ represents 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 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 2004 to July 2016.

Data

Live cattle cash prices, head sold, and average weight of live cattle marketed are taken from Livestock Mandatory Price Reporting (LMR) data compiled by the USDA Agricultural Marketing Service (AMS) and reported by Livestock Marketing Information Center (LMIC).[4] Data were collected for the five major reporting regions from June 2004 to July 2016. Weekly live cattle price is the price of live steers, averaged over all grades. Live cattle data for weight and head marketed are based on negotiated transactions of live and dressed steers and heifers. Weekly live cattle weight is a weighted average of all steers and heifers marketed via negotiation either as live or dressed

[4] The few missing prices (less than 1% of data) of live steers in the data were replaced by predictions based on regression analysis between related price series using the entire dataset. The three weeks of missing data that resulted from the government shutdown in October 2013 were dropped from the empirical analysis. In the case of Texas, three weeks had no price and weight observations. Kansas had one such week. These weeks were also dropped from the estimation. See N in table 2.

purchases.[5] Number of live cattle marketed via negotiation is the sum of animals marketed across these four categories. Number of live cattle marketed by non-negotiated methods is obtained by adding head of live cattle sold via forward contract, formula pricing, and non-negotiated grid sales. Futures prices are the weekly average of the nearby CME Live Cattle Futures contract taken from the Commodity Research Bureau (CRB) database for the same time period. These data were arranged by calendar week and used to calculate a weekly observed basis. An expected basis for each week was calculated as the simple average of the three previous years' basis in that calendar week. The dependent variable $BPE_{y,w}$ was calculated using equation (3) and measures hedging errors realized by participants hedging the negotiated sale of live steers.[6]

Right-side variables $\Delta AllHead$, $\Delta NegShare$, and $\Delta Weight$ were calculated using AMS data, following equation (4). The change in wages ($\Delta Wages$) was also calculated using equation (4) with monthly average hourly earnings of employees in the trade, transportation, and utilities industry (Bureau of Labor Statistics, 2016). *CornRatio* was specified using AMS cash corn prices and AMS cash price for live steers for each region. K was calculated using equation (5) based on CRB weekly average price of the CME Live Cattle Contract. Descriptive statistics for all variables are in table 1.

Results

Model Results

The data described in the previous section were used to specify the empirical model in equation (6). Augmented Dickey–Fuller tests showed that the five weekly regional time series of *BPE* were stationary. The five regional models were estimated separately. Since basis in the current period can be related to previous periods, it was suspected that there may be autocorrelation in the errors (Parcell, Schroeder, and Dhuyvetter, 2000). Given this and the fact that other live cattle basis studies dealt with autocorrelation (Parcell, Schroeder, and Dhuyvetter, 2000; Tonsor, Dhuyvetter, and Mintert, 2004), we tested for autocorrelation using the Durbin–Watson test. First-order autocorrelation was found in the errors of each model was corrected using a generalized least squares (GLS) approach.[7] Results are reported in table 2.

The interpretation of individual coefficients is the change in *BPE*, in terms of percentage of nearby futures price, given a 1% change in the relevant variable, *ceteris paribus*. The exception to this is *CornRatio*, which is a proportion not converted to percentage terms. Discussing a 1% change in any variable does not reveal much about how the volatility of that variable will economically impact *BPE* and hedging effectiveness. Therefore, only directional impacts and statistical significance will be discussed first. After that we offer a transformation of the coefficients that allows for analysis of economic importance of volatility in the explanatory variables.

$\Delta AllHead$ has a statistically significant, positive relationship with *BPE* in Iowa and Nebraska. In other regions, the effect is not statistically different from 0. Hedging in Colorado, Kansas, and Texas is unaffected by current level of live cattle marketings. Naik and Leuthold (1988) and Liu et al. (1994) similarly found that their respective measures of total cattle slaughtered had no effect on live cattle basis. $\Delta NegShare$ has a statistically significant impact on *BPE* in all regions, meaning that the relative thinness of the negotiated market affects ability to hedge in all regions. The direction of the impact is positive, which indicates $\Delta NegShare$ and *BPE* move in the same direction. From the perspective of a short hedger, as the negotiated market becomes relatively thinner, *BPE* decreases and net price received is lower than expected.

[5] Dressed weights were converted to live weight equivalents assuming a 63% dressing percentage.

[6] As three years' historical data are needed to calculate expected basis, *BPE* can only be calculated from 2007 forward. However, market data from 2004, the beginning of regional transaction type reporting by LMR, is being used in the calculation of *BPE*.

[7] Autocorrelation can also be a result of misspecification, where included or omitted variables being correlated across observations (Greene, 2004). The estimation was performed in SAS using PROC Autoreg with the ML (maximum likelihood) option for correcting for first-order autocorrelation.

Table 2. Weekly Basis Prediction Error Models Including Share of Live Cattle Sold via Negotiated Methods, 2007–2016

	Units	Colorado	Iowa	Kansas	Nebraska	Texas
Intercept		3.225**	2.842	2.066*	5.237**	1.245
		(1.437)	(2.002)	(1.125)	(1.463)	(1.195)
Shifts in Market Conditions						
ΔAllHead	%	−0.003	0.007**	0.004	0.008**	0.005
		(0.003)	(0.002)	(0.005)	(0.004)	(0.004)
ΔNegShare	%	0.016*	0.019**	0.045**	0.038**	0.023**
		(0.008)	(0.006)	(0.009)	(0.009)	(0.010)
ΔWeight	%	−0.035	−0.029	−0.110**	−0.074	−0.069**
		(0.022)	(0.025)	(0.036)	(0.052)	(0.020)
ΔWages	%	−0.984**	−1.222**	−0.860**	−1.353**	−0.709**
		(0.322)	(0.401)	(0.250)	(0.319)	(0.265)
Contemporaneous Factors						
CornRatio	bu/cwt	0.090**	0.155**	0.117**	0.081**	0.125**
		(0.025)	(0.037)	(0.020)	(0.024)	(0.024)
K	%	−0.013**	−0.027**	−0.014**	−0.014**	−0.016**
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Futures Contract Binary Variables						
Feb		0.192	0.277	0.512	0.435	0.513
		(0.525)	(0.514)	(0.428)	(0.499)	(0.444)
Apr		0.392	1.022**	0.378	0.340	0.380
		(0.443)	(0.402)	(0.366)	(0.413)	(0.378)
Aug		0.261	0.256	0.419	0.330	0.461
		(0.453)	(0.416)	(0.373)	(0.424)	(0.387)
Oct		0.250	0.164	0.435	0.415	0.364
		(0.528)	(0.517)	(0.430)	(0.502)	(0.447)
Dec		−0.547	−0.329	−0.275	−0.225	−0.227
		(0.536)	(0.541)	(0.434)	(0.513)	(0.452)
R-squared		0.08	0.19	0.19	0.14	0.13
Durbin–Watson Statistic		2.18	2.13	2.13	2.16	2.14
N		474	474	473	474	471

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

As predicted, if cattle sold in a region are heavier than the average weight of the last three years, *BPE* is more negative as actual basis is weaker than expected basis. This corresponds with Parcell, Schroeder, and Dhuyvetter (2000), who found increasing weights weaken live cattle basis, though these impacts in their study were not statistically significant for the three regions studied (Colorado, Kansas, and Texas). In the current study, the coefficient on Δ*Weight* is statistically different from 0 in Kansas and Texas. Given *a priori* expectations that the impact of Δ*Weight* on *BPE* is negative, the standard errors in table 2 were used to perform a one-tailed test of significance as to whether the coefficient is less than 0. Statistically, the coefficient on Δ*Weight* is negative in each region at the 10% level. Such a result is expected since short-term fluctuations in weight of negotiated cattle could make those cattle differ from the average weight specified by the CME Live Cattle Contract and, therefore, cause basis to change relative to historical levels. This implies a short hedger would receive a lower net price than predicted as average weight of negotiated cattle increases. Note that this measure does not consider per head profit, which might improve when selling heavier animals, but only the net price received per hundredweight relative to expectations.

Coefficients on change in wages (Δ*Wages*), which is included as a proxy for delivery costs, also have signs consistent with *a priori* expectations and are statistically significant in all regions. As delivery cost increase, basis weakens, causing *BPE* to become more negative. Though direct comparison is not straightforward, Liu et al. (1994) also found the effect of delivery cost on live cattle basis to be negative and statistically significant. Delivery costs, which may often be overlooked since they are more dependent on macroeconomic factors than on factors directly related to cattle feeding, are important determinants of hedging effectiveness.

The variable *CornRatio*, which approximates the marginal benefit of adding pounds to live cattle, is positively related to *BPE*, as expected. That is, when the corn price decreases relative to fed cattle cash price (or fed cattle cash price increases relative to corn price), basis strengthens. Parcell, Schroeder, and Dhuyvetter (2000) used nearby corn futures as a proxy for feed costs and also found that an increase in feed cost weakens local basis. However, in an earlier analysis of live cattle basis Naik and Leuthold (1988) found lagged corn futures to have no statistical impact on basis. Price momentum, as measured by the stochastic oscillator *K*, has a statistically significant, negative impact on *BPE* in all regions. The magnitude of the impact is similar for four regions, with Iowa the exception. The negative sign on the coefficient indicates that rising (falling) nearby live cattle futures price outpaces local cash price, causing basis to weaken (strengthen) compared to historical levels. The statistical significance of the coefficients on *K* reveals that market trends influence *BPE* and ability to effectively hedge live cattle using the CME Live Cattle Futures Contract.

Futures contract month dummy variables, with the exception of the April contract in Iowa, had no significant impact on *BPE*. Hedgers could execute equally effective hedges utilizing any of the six available contracts. This says nothing regarding how well any contract performs but simply that all available contracts perform equally well for hedging against live cattle price risk from a basis prediction perspective.

Impacts of Volatility of Economic Variables

As mentioned, it is more interesting to consider how the relative volatility of the right-side variables affects *BPE* (and, thus, net price received by a short hedger) in monetary terms. As the dependent variable, *BPE*, is in terms of percentage of nearby futures price, it is possible to convert coefficients of continuous right-side variables to dollars per hundredweight by simply multiplying them by an assumed nearby futures price. From there the result can be multiplied by the standard deviation of the right-side variable to arrive at the impact on *BPE* due to a 1-standard-deviation increase in the relevant right-side variable. We closely follow Marsh (2001) and use the standard deviations as approximations for volatility in explanatory variables of interest, which ensures that the results are based on changes in the economic variables that are realistic over the time period being examined.

Over 2004–2016, the mean of the nearby CME Live Cattle Contract futures price series was \$108.70/cwt and the standard deviation was \$24.04/cwt. Based on these numbers, we assume two price levels for the nearby futures: an average level of \$110/cwt and a high level (approximately the mean plus 1 standard deviation) of \$135/cwt. Impacts of a 1-standard-deviation increase in the independent variables at these nearby futures price levels are shown in table 3. No consideration is given as to whether a shift in any variable is more or less likely at a given price level, and shifts in each variable are assumed to occur while holding all other variables constant. Across all regions, upward volatility of negotiated cattle's market share (Δ*NegShare*) increases *BPE* and net price received for short hedgers. The largest impact is realized in Kansas, where, assuming a futures price of \$110/cwt, an increase of 9.9% in the negotiated share of live steers and heifers marketed (relative to the three-year average) is associated with \$0.50/cwt increase in *BPE*. The impact of

Table 3. Estimated Impacts in $/cwt on Basis Prediction Error Due to a 1-Standard-Deviation Increase in Economic Variables

Nearby Futures Price	Economic Variable	Colorado	Iowa	Kansas	Nebraska	Texas
$110/cwt	$\Delta AllHead$	−$0.06	$0.20	$0.07	$0.15	$0.08
	$\Delta NegShare$	$0.17	$0.24	$0.50	$0.41	$0.17
	$\Delta Weight$	−$0.12	−$0.07	−$0.29	−$0.13	−$0.26
	$\Delta Wages$	−$0.71	−$0.88	−$0.62	−$0.98	−$0.51
	CornRatio	$1.00	$2.04	$1.31	$1.04	$1.21
	K	−$0.48	−$0.99	−$0.53	−$0.52	−$0.57
$135/cwt	$\Delta AllHead$	−$0.08	$0.24	$0.08	$0.18	$0.10
	$\Delta NegShare$	$0.21	$0.29	$0.61	$0.50	$0.21
	$\Delta Weight$	−$0.15	−$0.09	−$0.36	−$0.16	−$0.32
	$\Delta Wages$	−$0.87	−$1.09	−$0.76	−$1.20	−$0.63
	CornRatio	$1.22	$2.50	$1.61	$1.27	$1.48
	K	−$0.59	−$1.22	−$0.65	−$0.64	−$0.70

Notes: Values in the table are the result of multiplying the standard deviation of each explanatory variable (table 1) with estimated coefficient on the same variable (table 2). As explained in the text, results can also be interpreted as the change in net revenue experienced by a short hedger due to basis prediction error.

variation in proportion of cattle negotiated is less pronounced in other regions, especially in Texas. This is not surprising, as live cattle market in Texas moved away from negotiated sales long ago and volatility in this measure is low in Texas, relative to other regions.

Volatility in delivery costs (as proxied by $\Delta Wages$) has a statistically significant impact in all regions, but magnitudes vary. Nebraska basis is most sensitive to shifts in delivery costs where the model predicts that a 1-standard-deviation shift (0.66%) in wages of transportation workers decreases *BPE* by $0.98/cwt at the average futures price level. Volatility in the *CornRatio* variable (a proxy for net benefit of adding pounds to live cattle) has the largest impact of any explanatory variable across all regions. The largest effect is realized in Iowa, where a 1-standard-deviation increase in *CornRatio* results in a $2.04/cwt increase in *BPE*. Iowa has the highest average *CornRatio* of any region (table 1), which means that, on average, the net benefit of feeding cattle longer is higher in Iowa than in other regions. However, *CornRatio* in Iowa is also relatively more variable, as it has a larger standard deviation than *CornRatio* in other regions. As a result, the model predicts *BPE* in Iowa is more responsive to volatility in *CornRatio* than *BPE* in other regions.

Lastly, the impact of market trends, as measured by stochastic oscillator K, is statistically significant across all regions. A 1-standard-deviation increase in K decreases *BPE* by anywhere from $0.48–$0.99/cwt, depending on the region. An increase in K indicates an overbought market (or at least a trend in that direction). Model results show that short hedgers fare worse in overbought markets. The impact of the volatility of market trends is the greatest in Iowa.

Results reveal insightful relationships between market factors and basis prediction errors. Shifts in relative share of cattle in the negotiated market and shifts in the weight of those cattle impact ability to hedge. Unexpected shifts in economic conditions also have a strong impact on hedging effectiveness. Volatility in *CornRatio* and $\Delta Wages$ tends to have the largest impact on *BPE* of all the variables analyzed. Price trends, as measured by K, also have a statistically significant and consistent impact across all regions.

Conclusions

Hedging live cattle price risk effectively requires the ability to understand and predict basis. Errors predicting basis result in discrepancies between expected price and actual price received, decreasing the risk management potential of hedging. We proposed a framework to analyze basis prediction errors in each of the five major LMR live cattle reporting regions. As basis is often predicted by a three-year moving average, relevant market variables were measured in terms of deviations from a three-year moving average. The resulting models estimate impact of shifts in market conditions compared to the previous three years on basis prediction errors. Two contemporaneous variables were also included. One was the ratio of local corn price to local cash live cattle price to represent the marginal benefit to feeders of adding more pounds to live cattle. The second was a stochastic oscillator measuring price momentum. The stochastic oscillator serves as a proxy for market trends not captured by other economic variables. Binary variables for futures contract months were included to control for differences in performance across contracts. The resulting models are a novel approach to modeling live cattle hedging effectiveness and one of the few studies to simultaneously do so across multiple regions of the country.

Results show that all futures contracts generally perform equally well across the five market regions. With the exception of the April contract in the Iowa market region, no inherent bias exists in basis predictability in any region for any given contract. Beyond the contract effects, results highlight the diversity of live cattle markets across regions. Share of live cattle sold via negotiation is positively related to basis prediction error in every region. During a time of increased proportion of negotiated marketings, short hedgers realize a stronger basis than expected and, therefore, a higher net price than predicted. The magnitude of the impact is largest in Kansas and Nebraska, where negotiated markets represent a larger portion of cattle marketed compared to other regions. When cattle marketed are heavier, on average, than those sold in the same week over the last three years, predicted basis overestimates observed basis. Basis prediction errors in Kansas are most responsive to deviations for average weights. Understanding these regional differences can improve producer planning. For example, if heavier than average cattle are being sold, feeders in Kansas and Texas can anticipate a weaker than expected basis when they lift their hedges, but the same is not true for other regions.

Basis prediction errors are sensitive to changes in delivery costs in all regions. Wages are used here to approximate delivery cost since the driver's time is a large component of that cost. As economic conditions cause alternative employment opportunities for drivers to decrease or increase, delivery costs will fluctuate. This highlights the need to consider macroeconomic conditions when analyzing hedging effectiveness. Of all the explanatory variables examined, the volatility of the ratio of live cattle price to corn price has the most pronounced effect on basis prediction error. Iowa producers should be especially aware of this local ratio, as its impact on basis prediction error in Iowa is larger than other regions. Market trends (as measured by the stochastic oscillator) also statistically impact ability to hedge live cattle cash price risk. However, volatility in market trends is not the largest contributor to basis prediction error during the time period studied.

The findings from this study emphasize the local nature of basis and the need for hedgers to understand their specialized conditions. For example, Iowa basis prediction errors are more strongly affected than other regions by volatility in delivery costs. This makes sense given that Iowa feedyards are located farthest from the major packing plants. Another key finding is that volatility in fundamental factors like net benefit from adding pounds to cattle and delivery costs have greater effects on basis prediction error than do market trends. Future efforts to examine the effectiveness of hedging with the CME Live Cattle Contract should utilize these findings to carefully consider the complex and changing factors that affect ability of producers to use the contract to hedge.

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Appendix: Alternative Model Formulation

The model formulation presented in the paper (equation 6) measures live cattle marketing trends using two measures: (i) Δ*AllHead* is change in total steers and heifers sold via as negotiated live, negotiated dressed, forward contract, and formula pricing and (ii) Δ*NegShare* is the change in the percentage of those cattle marketed on negotiated basis. The economic reasoning for this modeling choice can be found in the text of the paper. An alternative choice would be to measure both the negotiated and non-negotiated markets in absolute terms. We considered this option and include the results in this appendix. The data used to specify the model are the same as those described in the paper. However, in this formulation, live cattle markets are modeled using two alternative variables: (i) Δ*NegHead* is the change in steers and heifers sold on a negotiated basis (both live and dressed) and (ii) Δ*NonNegHead* is the change in steers and heifers sold via forward contract and formula prices, which do not involve traditional negotiation.

Signs and magnitudes of all variables common to both formulations are very similar, demonstrating a robustness of the findings regarding cattle weight (Δ*Weight*), impact of delivery costs (Δ*Wages*), net benefit of adding pounds to cattle (*CornRatio*), and market trends (K). The absolute level of negotiated cattle marketed (Δ*NegHead*) has a statistical impact on four of the five regions. The impact is positive, just like that of the relative level of negotiated cattle (Δ*NegShare*). The biggest disadvantage of this model is that changes in Δ*NegHead* and Δ*NonNegHead* can conceivably come from either a change in the aggregate supply of live cattle or a change in marketing methods in a given region. Since the modeling choice in the paper allows for these two impacts to be decoupled, it was chosen as the more economically appropriate to present. The alternative formulation is included here as a comparison.

Table A1. Weekly Basis Prediction Error Models Including Levels of Live Cattle Sold via Negotiated and Non-Negotiated Methods, 2007–2016

	Units	Colorado	Iowa	Kansas	Nebraska	Texas
Intercept		4.621**	3.915**	2.979**	6.423**	2.640**
		(1.504)	(1.887)	(1.181)	(1.501)	(1.251)
Shifts in Market Conditions						
Δ*NegHead*	1,000 head	0.037	0.051**	0.045**	0.033**	0.028**
		(0.025)	(0.008)	(0.006)	(0.006)	(0.007)
Δ*NonNegHead*	1,000 head	−0.019	−0.013	−0.018*	−0.014	0.000
		(0.015)	(0.009)	(0.009)	(0.011)	(0.006)
Δ*Weight*	100 pounds	−0.257	−0.249	−0.802**	−0.580	−0.568**
		(0.169)	(0.190)	(0.285)	(0.392)	(0.162)
Δ*Wages*	$/hour	−9.009**	−8.896**	−7.225**	−10.894**	−7.150**
		(2.288)	(2.491)	(1.808)	(2.206)	(1.902)
Contemporaneous Factors						
CornRatio	bu/cwt	0.124**	0.155**	0.141**	0.114**	0.156**
		(0.028)	(0.036)	(0.022)	(0.026)	(0.026)
K	%	−0.014**	−0.027**	−0.015**	−0.015**	−0.017**
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Futures Contract Binary Variables						
Feb		0.206	0.295	0.508	0.434	0.502
		(0.523)	(0.510)	(0.424)	(0.494)	(0.441)
Apr		0.398	1.041**	0.354	0.340	0.434
		(0.441)	(0.401)	(0.363)	(0.411)	(0.375)
Aug		0.233	0.287	0.428	0.292	0.476
		(0.450)	(0.414)	(0.370)	(0.421)	(0.384)
Oct		0.200	0.183	0.360	0.374	0.355
		(0.525)	(0.513)	(0.425)	(0.497)	(0.445)
Dec		−0.594	−0.288	−0.321	−0.323	−0.252
		(0.533)	(0.536)	(0.430)	(0.507)	(0.449)
R-squared		0.09	0.19	0.21	0.15	0.15
Durbin–Watson statistic		2.18	2.11	2.14	2.15	2.15
N		474	474	473	474	471

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