Cross-Hedging Bison on Live Cattle Futures

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Abstract

Bison production is an emerging retail meat industry. As demand increases, it creates opportunity for supply-side growth. However, the bison market is volatile and the potential for a drop in the value of bison makes price risk an important factor for producers. Following price risk theory, hedging opportunities for bison producers are investigated using the live cattle futures contract. For the time periods researched, there is no clear evidence that cross-hedging reduces price risk for bison producers. However, there is a possibility that after the bison industry becomes more established and consumer knowledge plays lesser of a role in prices, cross-hedging strategies will be advantageous to producers.

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Chapter 1 – Introduction

1.1 Motivation for this Study

More commonly known as the American buffalo, bison are a North American trademark dating back to Native Americans and westward expansion. In the late 1800's bison were nearly extinct. However, through public and private efforts, wild bison were preserved and herds were rebuilt to healthy levels. In 1966 excess animals in the United States were first auctioned for meat production. Bison meat is now an emerging market, first introduced to the United States Department of Agriculture's (USDA) Agricultural Marketing Service (AMS) Annual Meat Trade Review in 2005. Over the past decade bison prices have continued to rise because of increased demand for natural and organic meat products (Greene 2012). According to the American Meat Institute (2014), today's consumer pays more attention to how meat items are produced, processed, and packaged. Bison producers have caught consumers' attention by aggressively marketing bison meat as a healthier beef alternative that is naturally raised and humanely produced. To meet an increasing demand, the National Bison Association is actively recruiting new producers to expand the industry (NBAC 2014).

As the bison market continues to evolve, an impending drop in the value of bison becomes an economic threat that could hinder the industry's growth. In 2011, 14% less bison were processed at USDA and state-level inspected plants relative to the three-year moving average. Producers held back animals in order to expand their herds. As bison herds expand and stock values moderate, more producers will enter the industry and supply may eventually meet, or even surpass demand (Hansen and Geisler 2012). If bison demand growth remains strong, bison prices could remain favorable to producers with supply expansion. However, if supply outstrips demand, the value of bison could eventually drop, making price volatility a big factor of ranch management during the marketing year.

In addition to a potential drop in bison value, the market has been quite volatile. For the 9.75-year time span of June 2004 through March 2014, the coefficient of variation for bison carcasses per hundredweight (cwt) is 34.6%, meaning that the standard deviation of bison prices during the period is 34.6% of the mean. This is a particularly high coefficient of variation compared to other protein commodities examined over the same period: Chicago Mercantile Exchange (CME) live cattle futures contract prices have a coefficient of variation of 17.0% and CME lean hog futures contract prices have a coefficient of variation of 17.6%. More recently, bison's coefficient of variation is only slightly higher than those seen when looking at the live cattle and lean hog prices. When looking at the 4-year period (March 2009-March 2013) bison prices' coefficient of variation is 19.5%, CME live cattle futures prices' coefficient of variation is 16.1% and CME lean hog futures prices' coefficient of variation is 16.7%. The coefficients of variation show that bison prices consistently have higher volatility in than live cattle and lean hog prices. Bison producers can aggressively market their output to expand demand, but their only price risk management tool is to forward contract to meat processors. In the presence of a volatile evolving market, bison producers may want an additional tool to manage their price risk.

Large-scale farmers in commodity markets can manage prices by hedging in the futures market. Futures contracts are available with standardized specifications for commodities such as cattle, corn, wheat, lean hogs, etc. Hedging is a standard tool to ensure cash flows by reducing the risk of unfavorable price movements in the cash market. A commodity hedge consists of taking an offsetting position in the futures market. For example a corn farmer anticipating to harvest his corn could hedge his crop by selling an appropriately dated corn futures contract stating that he would sell corn at a set price. When the farmer eventually sells his harvested crop, he offsets his futures hedge by buying back his corn futures contract. If prices drop during the period, the farmer gains on his futures position and loses on his cash position, and vice-versa if prices rise. Hedging does not usually increase the net cash flow, but rather smoothes the distribution of price variability. In fact, hedgers give up the opportunity to benefit from a favorable price change in order to obtain protection from an unfavorable price change.

Bison are not traded on commodity futures markets; therefore, producers are unable to manage price risk through direct hedging. As a result, price uncertainty could deter new ranchers from entering the market, and inhibit the market's expansion. To encourage market growth, this study examines the potential for cross-hedging using a suitable futures contract proxy. Cross-hedging is the act of hedging with a different but related product's futures contract. Although the two goods are not identical, using the proxy's futures contract for hedging purposes is viable if the price movements of the proxy product are similar to those of the cash price for the commodity being produced. Following the theory set forth by Bressler and King (1970), and Blank and Thilmany (1996), future contracts are assessed across time, space and product form in order to find the most suitable contract to evaluate for cross-hedging potential.

1.2 Objectives of the Study

This paper specifically aims to investigate cross-hedging possibilities for the bison industry. Often cross-hedgers use contracts for commodities that are substitutes or important inputs to their cash position. For example, research has been accumulated in regards to cross-hedging various bovines and wholesale beef byproducts using the live cattle contract (Carter and Loyns 1985, Blank and Thilmany 1996, Hayenga DiPietre 1982). Our first objective in this paper is to analyze the bison market across time, space, and product form in order to find an appropriate futures contract proxy. Next, the formulation and evaluation of cross-hedge ratios are assessed. Literature on the optimal hedge ratio, dating back to 1960, is used to assess what proportion of the cash position should be hedged. (Johnson 1960, Benninga, Elenor and Zilcha 1984). Stationarity is assumed in the optimal hedge ratio model, and is likely violated by the uptrend in bison prices. More sophisticated econometric models have been developed to correct models with nonstationarity (Engle 1982, Bollerslev 1986). This study aims to apply existing cross-hedging analysis techniques to the unique bison market. Finally, a cross-hedging example is examined to clarify how estimated hedge ratios can be applied.

Chapter 2 – Literature Review

2.1 Cross-Hedging Theory

The major function of futures markets is to transfer price risk from hedgers to speculators; hedgers participate to reduce their cash market risk and speculators undertake risk in hopes to gain. Hedging reduces price variability by ensuring monetary losses in the cash market are offset by gains on the futures market, and vice-versa. When gains and losses are equal, the hedge is known as a "perfect hedge." A perfect hedge is risk free and locks in a cash market value at the time the hedge is placed. Perfect hedges are extremely rare due to the presence of basis risk and the use of standardized futures contracts. Basis is known as the cash price minus the futures price at a certain point in time, *t*.

(1) $Basis_t = Cash\ Price_t - Futures\ Price_t$

In practice, the gain or loss on a hedge will depend on the basis at two points in time, when a hedge is placed and when it is lifted. The possibility of a change in basis is known as basis risk. Therefore, hedging involves the substitution of basis risk for price risk. Basis risk is present in most hedges due to cash commodities differing in location, or delivery date from the standardized contract. In order for a hedge to be perfect, it is also necessary that the hedge ratio is 1:1; where the futures hedge offsets 100% of the cash position. This is unrealistic due to the unlikelihood that the size of the cash position exactly matches that of standardized futures contracts.

De facto, most hedgers do not hedge their entire cash position, but rather a proportion of their position based on their utility maximizing hedge ratio. The utility maximizing hedge ratio balances the hedger's personal desire to lower risk with their desire to benefit from a favorable cash price. The portfolio approach is based on a utility function that simultaneously takes into account the expected return and variance of the combined position. Nevertheless, many hedgers prefer a simple risk-minimizing hedge ratio even though it does not consider cash position gain.

Many agricultural commodities do not have an active futures market, presenting a problem if one wants to reduce price risk through hedging. Cross-hedging involves hedging a cash commodity with a different commodity's futures contract (Hieronyus, 1997). According to Heironyus' (1997), cross-hedging will generally work if the price of the commodity being cross-hedged and the price of the futures are closely related and follow one another in a predictable manner. Anderson and Danthine (1981) stress the fact that most hedging decisions are akin to cross-hedges; that is, they involve a cash good that differs in type, grade, location, or delivery date from the standardized contract. They argue that the presence of basis risk means that hedges involving portfolios of futures contracts may be preferable to those involving only a single futures contract. According to their theory, risk reduction is achieved through dealing with multiple contracts, and cross-hedges are in order whenever price relationships between the spot and futures price produce a correlation coefficient significantly different from zero; suggesting that using partial correlation coefficients between the spot and a specific futures contract is a good evaluator of the usefulness of that contract for hedging purposes. However, Anderson and Danthine (1981) admit to ignoring the problem of standardized futures contracts that must be traded in integer quantities. For small hedgers, this discrepancy may eliminate the possibility of using multiple contract cross-hedges. Even large hedgers may find that the discreteness limits the number of contracts that should be considered in the portfolio.

2.2 Optimal Hedge Ratio

Johnson (1960) finds the "perfect hedge" ratio of 1:1 to be inadequate for cross-hedgers because it requires that futures and cash prices be perfectly correlated. For imperfect cross-hedges, Johnson (1960) uses portfolio theory to derive the variance-minimizing hedge, which determines the proportion of the cash position price exposure that should be hedged. Price risk in the cash and futures market is explained as the standard deviation of the change in the price during the hedging period from t_1 to t_2. In Johnson's model, x_j^* is the unit position in the "hedging" market *j*, x_i is the unit position in cash market *i*, cov_{ij} denotes the covariance of the price change between market *i* and market *j*, and σ_j^2 is the variance of the price change in market *j* for the duration of the hedge. x_j^* units is set at a value to minimize the price risk of holding both x_i and x_j^* units for the duration of the hedge. Johnson provides the following equation for x_j^*:

(2) $x_j^* = -\frac{x_i cov_{ij}}{\sigma_j^2}$

Equation (3a) provides the framework for the minimized variance of return equation:

(3a) $V(R)^{*} = x_i^2\sigma_i^2 + x_j^2\sigma_j^2 + 2x_ix_jcov_{ij} = x_i^2\sigma_i^2(1-\rho^2)$

The price risk of holding x_i units during the hedging period is equal to $x_i^2\sigma_i^2$, and ρ is the coefficient of correlation for the price changes in market *i* and *j* during the hedge duration. Price changes are analyzed in order to analyze the variance of returns not prices. A larger correlation coefficient indicates greater opportunity for hedging risk, thus a correlation coefficient with the value of one follows the perfect hedge ideology of taking an equal and opposite position in the spot and futures market. Equation (3b) describes the returns equation, R found in (3a):

(3b) $R = x_iB_i + x_jB_j$

Where B_i and B_j denote the actual price changes in markets *i* and *j* from the initiation of the hedge at t_1, to the time the hedge is lifted at t_2. Benninga, Eldor, and Zilcha (1984) and Kahl (1983) demonstrate that Johnson's equation for the minimum variance hedge ratio can easily be manipulated to a regression of cash on futures using price levels instead of price changes.

Benninga, Eldor, and Zilcha (1984) show, that following two assumptions, the minimum variance hedge ratio is also an optimal hedge ratio. The first assumption is that the futures market is an unbiased predictor of the future spot. The unbiasedness assumption means the producer's income is unaffected by his futures position. Therefore, the only reason to hedge inventory is to reduce price risk. In previous literature, the hedge ratio that minimized the variance of price was not necessarily optimal because optimality was defined by maximizing producer's utility (Anderson and Danthine 1981). The unbiasedness assumption makes it unnecessary to consider the producer's utility function, and strengthens previous work by Johnson (1960). The second assumption is that at t=1, when the hedge is lifted, the prevailing cash market price $\widetilde{P_1}$(tildes denote uncertainty at the initiation of the hedge t=0) is a linear function of the futures price $\widetilde{F_1}$. The 'regressability' assumption allows the optimal hedge ratio to be evaluated at price levels, instead of price changes, as proposed by Johnson (1960). The following basic model is used to cross-hedge.

(4) $\widetilde{P_1} = a + b\widetilde{F_1}$

Under those assumptions, the slope coefficient b is identified as the 'optimal' minimum variance hedge ratio that is independent from risk-aversion.

Brown (1985) argues that theoretical and statistical problems occur when price levels are used to test the optimal hedge ratio. Statistically, if corresponding trends exist in spot and futures prices, high levels of correlation may be present between price levels, but not between price changes. Brown (1985) is also concerned that residuals of price level regressions often exhibit significant degrees of autocorrelation; violating the assumptions of the ordinary least squares (OLS) model and resulting in inefficient hedge ratio estimates. Brown (1985) suggests that the use of price changes in the OLS regression is more appropriate to find an accurate optimal hedge ratio. Using price changes to solve the optimal hedge ratio is minimizing the variance of returns, as opposed to using price levels to minimize the variance of price. The regression of price changes is as follows:

(5) $\Delta P_1^C = \gamma_0 + \beta_1 \Delta P_1^f + \varepsilon$,

where ΔP_1^C is the cash market price change during the duration of the hedge, ΔP_1^f is the futures market change in price during the duration of the hedge, and β_1 represents the optimal hedge ratio with γ_0 representing the intercept term. Wilson (1987) and Carter and Loyns (1985) also support this theory.

2.3 Hedge Ratio Modifications

Myers and Thomson (1989) propose a generalized approach to optimal hedge ratio estimation that uses more variables to specify the equilibrium-pricing model. They argue against the simple regression approach because the slope parameter, also the hedge ratio, only gives a ratio of the unconditional covariance between cash and futures variables to the unconditional variance of the futures variable. Myers and Thomson adjust the model to consider relevant market information available at the time the hedging decision is made. Examples of additional variables include: lagged values of spot and futures prices, production levels, storage, exports, and consumer income. Below is an example of the generalized model with the addition of lagged dependent variables to the regression:

(6) $P_t = \beta_0 + \beta_1 F_t + \beta_2 P_{t-1} + [\dots] + \varepsilon$

P_t is the cash price at time t and F_t is the futures market price at time t. Myers and Thomson suggest adding lags because past prices may help predict future prices. The decision on exactly which variables to include and what lag lengths to use will be determined by both economic theory and length of available data. Myers and Thomson suggest including a large number of lagged variables, i.e. storage, production, etc., to account for all relevant conditioning information. However, the procedure leads to biased estimates even if the spot price change depends on the information set. For example, equation (6) is a system of stochastic difference equations that deliberately over fits the model. Myers and Thomson point out that comparing the performance of the simple regression and generalized approach provides information on the benefits of adopting the generalized approach.

Viswanath (1993) modifies Myers and Thomson's procedure by considering current basis information. The model follows Fama and French's (1987) argument that the basis at the initiation of the hedge should have the power to predict the changes in the spot and futures price. The basis corrected hedge ratio estimate is equivalent to the slope variable b_{BC} in the following model:

(7) $P_T - P_t = a_1 + b_{BC}(f_T - f_t) + c(f_t - P_t)$,

Where P_t and f_t are the prices of spot and futures when the hedge is initiated at time *t*, P_T and f_T are the prices of spot and futures when the hedge is lifted at time *T*, and $(f_t - P_t)$ represents the basis at the beginning of the hedge. In order for the model to hold, the expected futures must be a function of the current basis. If this is true then the basis corrected hedge ratio should be different and significantly greater than the traditional regression estimate because the hedge ratio does not need to reflect the variation in the beginning basis. By including basis information into the estimation, Viswanath also accounts for the possibility of cash-futures convergence at the hedge's maturity, improving previous theory set forth by Myers and Thomson. Viswanath's approach mainly produced returns with significantly smaller variances. However, it did not hold across the commodities analyzed, including corn, wheat and soybeans.

2.4 Addressing Nonstationarity

Several optimal hedge ratio approaches use a form of a simple or multiple ordinary least squares (OLS) regressions. However often spot and futures' prices violate the OLS time-series assumption that the price movements of data series follow a stationary process (Myers and Thomson 1989, Herbst et al., 1993). A stationary process is one whose probability distribution is stable over time, in the sense that any set of values in the time period will have the same mean and variance distribution. Thus, any data exhibiting a trend will fail to meet the stationarity requirement because the mean changes over time. Nonstationary OLS estimators are still unbiased and linear, however, confidence intervals and hypothesis tests based on the t and F distributions are unreliable. Dickey and Fuller (1979, 1981) developed unit root tests that are widely used in cross-hedging theory to determine if nonstationary models can be manipulated to render the data stationary (Nolte and Muller 2011, Bowman 2005). The usual procedure for correcting the presence of a unit root is to 'de-trend' the data by specifying the first difference form (or higher order forms, if necessary). Additional Dickey-Fuller tests can be used to test for other causes of nonstationarity. Assuming there is no drift or trend in the data, testing for a unit root is done by estimating a model without a constant, where Y_t is a data point at time t and Y_{t-1} is a data point lagged one observation in time:

(8) $Y_t = \beta Y_{t-1} + \varepsilon_t$

The null hypothesis assumes the presence of a unit root, where $\beta = 1$. If β is not statistically significant, the null hypothesis is rejected if there is reason to believe there is nonstationarity due to a drift, it is possible to test for both a unit root and drift with model (9). A drift is a slow and steady change that can occur if the variable in question experienced some sort of shock, such as an information shock, policy shock, market shock, etc. If bison experienced a positive demand shock due to marketing, live cattle and bison prices would drift apart, in spite of the fact that price signals may still be transmitted from one market to the other.

(9) $Y_t = \alpha + \beta Y_{t-1} + \varepsilon_t$

The presence of a drift will be reflected in the constant, stating if the drift dominates the series over time. If there is a drift, the data series is nonstationary irrespective of whether there is a unit root. This means both $\hat{\alpha} = 0$ and $\hat{\beta} = 1$ must be tested. Instead of a drift, the series may have a deterministic trend. Where t is a point in time corresponding to each data series, the test for a unit root and deterministic trend is written as:

(10) $Y_t = \alpha + \beta t + \rho Y_{t-1} + \varepsilon_t$

Now α is just a constant and the deterministic trend is captured by βt. Like with the drift, a time trend can lead to nonstationarity alone. Thus, both $\hat{\beta} = 0$ and $\hat{\rho} = 1$
Must be tested.

The Dickey-Fuller tests require that errors be unconditionally homoskedastic i.e. have no autocorrelation. This means that residuals are random and do not show an identified pattern when plotted. Heteroskedasticity is said to occur when the variance of the error terms is a function of the independent variables or is not constant over time. Authors in cross-hedging literature find difficulties with the Dickey-Fuller approach because time-series residuals are frequently autocorrelated (Engle and Granger, 1987).

Engle (1982) suggested that autocorrelation might be a problem in time series data, noticing that large and small errors often occur in clusters. Engle proposed a more sophisticated econometric model for time series data known as the autogressive conditional heteroscedasticity (ARCH) model. The variance of a model's error term is typically treated as a constant, however the ARCH process allows conditional variance to change over time as a function of past errors. Empirically ARCH models call for a fixed lag structure to avoid negative variance parameter estimates (Engle 1982, Engle 1983, Engle and Kraft 1983). ARCH(1) models assume that the error variance is heteroskedastic with respect to the immediate past error value. The model allows for conditional volatility in the series, with large and small shocks in volatility clustering together. It is possible to model higher order ARCH models, however as earlier noted, such models are difficult to estimate because they often produce negative variance estimates. To solve this problem Bollerslev (1986) proposed an extension of Engle's framework known as the Generalized ARCH (GARCH) structure. GARCH allows for a more flexible lag structure by turning the autoregressive process of the ARCH model into an autoregressive process with the addition of an exponentially weighted moving average process, with greater weight on recent errors than distant errors. The GARCH(1,1) framework is widely applied in cross-hedging literature (Blank 1984, Brorsen, Buck, and Koontz 1998, Newton and Thraen 2013). The GARCH model assumes conditional heteroscedasticity with homoscedastic unconditional variance. In other words, it is assumed that the changes in variance are a function of a moving average of preceding errors, and these changes represent temporary random movements from a constant unconditional variance. Therefore, datasets will not fit the GARCH framework if they follow an exogenous unconditional heteroscedasticity that is independent from past errors. Baillie and Myers (1991) conclude that, when applicable, the GARCH model performs better than other dynamic or constant hedges, given the time-varying nature of the conditional distributions of commodity returns and their futures contracts. However, there is growing evidence that more sophisticated econometric models such as GARCH introduce too much noise to provide cost-effective hedges (for example Copeland and Zhu, 2006).

2.5 Empirical Studies

Hayenga and DiPietre (1982) analyze the use of live cattle futures to hedge wholesale meat for processing plants and merchandizers. Noting that wholesale beef prices frequently exhibit different seasonal demand patterns than the composite demand for beef products that is reflected in live cattle prices, Heyenga and DiPietre break down the year into six two-month segments. This allows them to analyze each futures contract period individually to determine if there is historical consistency in the proportional correspondence or basis relationship between the cash and futures prices.

Heyenga and DiPietre run an OLS regression of cash prices on futures prices:

(11) $CP_{ij} = a_{ij} + b_{ij}FP_i + u_{ij}$

Where CP_{ij} is the average daily cash price for the jth wholesale beef product during the contracting period *i* each year; FP_i is the average of the daily prices for the nearby live cattle futures contract during contracting period *i* each year; and u_{ij} is the error term. The model allows both the intercept and slope to vary by period to reflect seasonal demand periods. The interpretation focuses on the relationship between the cash and futures prices during the period that the hedge would be lifted. The coefficient of determination (R^2) reflects the proportion of the variation in average cash prices that is associated with the change in average futures price.

The standard error forecast (SEF) of the average futures price is used to evaluate the basis risk the hedger would face in the period. The SEF can be used to create confidence intervals that illustrate how approximately two-thirds of the variation from the expected average cash price (based on average futures prices) would fall between ± 1 standard error forecasts. The authors note that the 'acceptable' size of the SEF for a given hedge would vary greatly among firm managers based on their individual risk profile. The decision to cross-hedge is dependent on a manager's expectations of the cash and future markets, prevailing futures price, and the manager's level of risk aversion (Heyenga and DiPietre, 1982). They conclude that in some instances live cattle futures present opportunities for cross-hedging wholesale beef to improve risk management activities.

Blake and Catlett (1984) conducted a similar study on cross-hedging hay with corn futures. In order to find the proportion of hay that should be hedged with each contract, the authors run a multiple regression of cash prices on each futures contract. This follows theory presented by Anderson and Danthine (1981) that suggests the partial correlation coefficient between the spot price and futures contract is a good evaluator of the usefulness of that contract for hedging purposes.

Carter and Loyns (1985) perform an empirical study on hedging Canadian cattle with the U.S. live cattle contract. They explain that due to high basis risk, feedlots were better off unhedged. Referring back to equation (1), basis is the value of the cash minus futures price at a certain point in time. Hedging involves the substitution of basis risk for price risk. In order for a hedge to be attractive, basis risk must be less than cash price risk. Cash price risk is the magnitude by which the cash price may deviate from the mean cash price, and it is typically measured by variance or standard deviation. Basis risk is the magnitude by which the basis deviates from the average basis, and it is also typically measured by variance or standard deviation. If the cash and futures prices always change by exactly the same amount, there is no basis risk because the change in basis is zero. When changes in the cash and futures price are not equal, there is basis risk. The correlation coefficient measures the proportion of the variance in cash price changes that future price changes explain, therefore is positively related to the stability of the basis. Basis risk is defined by the following equation:

(12) $\sigma_B^2 = \sigma_{CP}^2 + \sigma_{FP}^2 - 2\rho\sigma_{CP}^2\sigma_{FP}^2$

Where σ_B^2 is the variance of basis; $\sigma_{CP}^2$is the variance of cash prices; $\sigma_{FP}^2$is the variance of futures prices; and ρ is the correlation coefficient between cash and futures prices. The magnitude of basis risk mainly depends on the correlation coefficient, where a higher ρ provides a lower basis risk.

Newton and Thraen (2013) investigate the opportunity to hedge class I milk under four scenarios. The first scenario considers the contract underlying the class I mover as an ex post analysis. The following two scenarios analyze the associated basis with the futures contracts that correspond with manufacturing milk (class III and IV). The final scenario considers the highest valued contract 90 days prior to the class I price announcement, as found in literature by Maynard et al. (2005). Newton and Thraen (2013) obtain generalized optimal hedge ratios following an augmented reduced form model that follows theory set forth by Myers and Thomson (1989). The model regresses the spot with the change in the futures price over the life of the hedge, and the highest valued contract and one-period lag basis for class III and IV as the relevant conditioning information. Two hedging intervals were used. A Dickey-Fuller test for a unit root is performed to ensure the model is not misspecified.

For misspecified equations, associated with the use of class III and IV milk contracts, Newton and Thraen estimated parameters of an ARCH(1)-GARCH(1,1) model "to allow for volatility clustering in the basis." They conclude that the GARCH model is successful in modeling the autocorrelated data. Next the GARCH model forecasts of basis were compared to the OLS forecasts of basis using a 12-month rolling average. The GARCH model forecast preformed notably worse than the 12 month rolling average forecast. Newton and Thraen conclude that GARCH models may be useful in forecasting the basis over short time horizons in class III milk, but have little power to predict basis over any time horizon when considering class IV milk.

Chapter 3 – Futures Market Proxy

3.1 Cattle Contracts as a Proxy

In this section the cattle and bison markets are assessed across time, space, and product form to provide reasoning for considering cattle contracts to hedge bison. A futures proxy is necessary because bison is not traded on a commodity exchange. According to the 2012 Census of Agriculture, the total beef herd is nearly 54 million head on about 728 thousand farms; while the total bison heard is only 162 thousand head on 2,600 farms. Beef and bison are produced almost exclusively for human consumption, and likely interact as protein substitutes with bison having a quality premium over beef. Bison is marketed as a natural product reared with no antibiotics or growth hormones. Bison also a healthier alternative to beef with lower fat, calorie, and cholesterol content. On the supply side, production costs and weather are important determinants in both markets. The biggest factor impacting the demand for beef is income, and that is likely an important factor for bison as well. Theory regards beef as a superior good, following the premise that an increase in personal income increases the demand for high quality beef more than other foods (Davis et al. 2008). Since bison is a new industry, it is important to spread awareness to consumers, making marketing an integral factor to bison demand. Beef, on the other hand, is already a well-known meat product, making marketing not as important.

3.2 Bison Industry

According to the 2012 Census of Agriculture the largest number of bison were raised and sold in South Dakota, Nebraska, Montana, Colorado, and Oklahoma. Both wild and domesticated bison in this area follow a late spring calving season (April-May) with any out of season births occurring later in the summer (Newell and Sorin 2003, Rutberg 1984). However other sources consider calving season to be a longer period of April-June (NBA 2014) or May-July (Greaser 1995). Bison calves are weaned when they are about 6 months old, with females weighing about 350 lbs. and males weighing about 425 lbs.

The two predominant finishing phases in the bison industry are grass finishing and grain finishing. Grass finishing involves grazing bison from weaning to target weight, often with the addition of mineral supplements and high quality hay in the winter/spring. Grass finished bison are typically finished on high quality forage 60-90 days prior to slaughter (Steenbergen 2010). Grain finishing involves feeding high protein grain supplements from weaning to target weight (Feist 2000). There also are several combinations of grain and grass finishing being used. It is common for producers to grain finish their animals 90-100 days prior to slaughter because it ensures a higher quality and consistency of the meat and ensures the most economical gain out of the animal (Anders and Feist 2010). Grain finished meat is also easier to market because it has a white fat color, while purely forage fed bison has a yellow fat color at slaughter, which is unfamiliar to new consumers (Steenbergen 2010).

The National Bison Association provides general guidelines for handling bison at time of slaughter. A bison bull is typically slaughtered between the ages of 18-30 months. The average live weight of a bison bull is between 950-1250lbs. with an ideal weight of 1130lbs., and the average carcass weight of a bison bull is between 550lbs.-725lbs. with an ideal carcass weight of 650lbs. Marketed heifers can be harvested at live weights as low as 800 lbs. (Anders and Feist 2010). The average dressing yield for bison is 57% of the live weight.

3.3 Cattle Industry

Cattle calving season and duration can have a great influence on the costs and production schedule of a cow-calf operation. Early spring (February-March) and fall (September-October) are the most popular calving seasons; however late spring calving (April-May) is not uncommon (Reuter 2003, Blasi et al. 1998). Every calving season has its advantages and disadvantages, so managers determine the appropriate season based on forage base, seasonality of markets, labor requirements, and weather patterns. Longer calving seasons (120 days or more) are used to achieve maximum conception rates, and short calving seasons (90 days or less) allow producers more opportunity to concentrate labor and produce uniform calves, which are easier to market.

Beef calves are weaned at around 6-10 months of age when they weigh 450-700 pounds. Heavier calves may leave for feedlots as soon as they are weaned for fast growth, while lighter weight calves may be sent to a backgrounder or stocker to continue grazing until they are 12-16 months old. Remaining calves are sent to graze until they reach about 700 lbs., when they are considered to be feeder cattle. Feeder cattle are cattle that are ready to go to feedlots to put on weight more aggressively through grain finishing. Calves typically leave for feedlots between 6-12 months of age, and most cattle remain on the feedlot for 4-6 months until they have reached the necessary weight for slaughter, when they are regarded as live cattle. Feedlots sell live cattle to meat packers who slaughter the cattle. The average slaughter weight and age for live cattle is about 1000-1,250 lbs. between the ages of 12-24 months.

3.3.1 Feeder Cattle and Live Cattle Futures Contracts

The CME feeder cattle futures contract is traded for the months of January, March, April, May, August, September, October, and November. The contract size is 50,000 lbs. of 650-849 pound feeder steers, including medium-large #1 and medium-large #1-2 frames. The contract is cash settled based on the CME Feeder Cattle Index. The sample consists of all feeder cattle auctions, direct trades, video sales, and Internet sale transactions within the 12-state region of Colorado, Iowa, Kansas, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas and Wyoming.

The CME live cattle futures contract is traded for the months of February, April, June, August, October, and December, with 13 delivery points in 7 states: Colorado, South Dakota, Kansas, Texas, Nebraska, Oklahoma, and New Mexico. The live cattle contract is 40,000 pounds of USDA 55% Choice, 45% Select, Yield Grade 3 live steers. However, all contract months prior to 2014 have carcass-graded delivery adjustments and quality graded delivery adjustments for yield grades. However, cattle aged 30 months or more, and/or outside the 1,050-1500 lb. range are not deliverable. An estimated dressing yield of 63% is used as a carcass-conversion for yield grade 3 live steers on the contract. This means that for yield grade 3 live steers, a 787.5 lb. carcass weight is equivalent to a 1,250 lb. live weight.

3.4 Conclusion

The live cattle futures contract is the most suitable proxy for assessing cross-hedging possibilities in the bison market because it's specifications across time, space, and product form most closely resemble bison's at time of slaughter. The live cattle exchange uses the delivery grade closest to the bison grade with similar market locations.

Chapter 4 – Methodology

The ability of bison producers to cross-hedge using live cattle contracts is dependent on the viability of optimal cross-hedge ratios. The literature reviewed in Chapter 2 is used as a template to assess these ratios. This chapter describes the processes and methods used in the study more thoroughly.

4.1 Price Relationship of Cross-Hedge

Theory set forth by Hayenga and Dipietre (1982) analyzes the technical feasibility of hedging wholesale beef products using live cattle futures. To account for different seasonal demand patterns, the authors break down the year into six two month segments and determine the degree of proportional correspondence between cash and future price movements within the period. The authors emphasize that prices do not have to move in parallel, but rather in a predictable proportional pattern, for a futures contract to be a useful hedging mechanism. Hedge ratios are formed based on the price relationship when the hedge is closed. The authors omit the last two weeks prior to a contract's expiration to minimize the risk of making delivery. The data is composed of average prices for each contract period: *February:* Dec. 7-Feb. 6; *April:* Feb. 7-Apr.6; *June:* Apr.7-June 6; *August:* June 7-Aug.6; *October:* Aug. 7-Oct. 6; *December:* Oct. 7-Dec. 6. Typically, 11 observations on cash and futures prices were used to estimate each model.

Bison follows a different calving season and a less uniform production process than live cattle. This could cause the bison market to exhibit a different seasonal supply pattern than live cattle. Following Hayenga and Dipietre (1982), the six live cattle contracts are used to analyze seasonality and determine which futures contracts best reflect bison price. Unlike Hayenga and Dipietre, three hedging periods for each contract are analyzed to find the most suitable hedge window. Hedging windows of one, three, and six months are analyzed for each contract month: February, April, June, August, October, and December. The month prior to the contract expiration is chosen as the period during which the hedge will be offset. This study assumes bison producers are partaking in an anticipatory hedge, meaning firms use futures contracts in anticipation of a cash transaction. Anticipatory hedgers often choose a delivery month that follows the expected date of liquidation to reduce the risk of being forced to offset the futures position before the anticipated cash transaction. Average monthly data prices are used in this analysis following the bison data provided.

First, the relationship between average monthly bison cash prices and monthly average live cattle futures prices for each selected time period is estimated using ordinary least squares. The basic model is:

(13) $CP_{ij} = \alpha_i + \beta_i FP_i + u_i$,

where CP_{ij} is the average monthly price of bison group *j* during the period *i* each year; FP_i is the monthly average of daily settlement prices for the nearby live cattle futures contract during the period *i* each year; and u_i is the error term. The models allow for the slope and intercept coefficients to vary for each period *i*, to reflect the seasonal basis. For CP_{ij} in equation (13) young bison bull prices and weighted average young bison prices are considered for the bison groups, *j*. Young bison bull prices are most appropriate for cross-hedge analysis, because they best compare to the live cattle futures specifications. However, weighted-average bison prices, based on head of young heifers and bulls, are also analyzed to assess further hedging possibilities.

Hedgers' main concern is a change of basis during the hedge duration. If the model shows that the futures and cash price relationship has behaved in a relatively proportional fashion during the hedging window, model estimates of the relationship can be used to develop a hedging mechanism for bison producers. The model's slope coefficient, β_i, reflects the typical change in the average bison price associated with a $1.00 change in the average futures price during each two-month contract period. The slope coefficient ratio, β_i:1, provides insight into the pound-for-pound hedging strategy for bison producers. If β_i is greater than 1, the hedger must take a larger position (β_i times larger) in the futures market than the cash market in order for the gains and losses of the markets to balance out.

Several statistics help measure the risk of a cross-hedge, such as the R-squared and the standard error of the forecast. The R-squared estimation, resulting from the estimation equation (13), represents the variability in the bison price that is associated with live cattle futures. The higher the R-squared, the stronger the relationship between the two commodity price series and the less risky the cross-hedge. To examine the magnitude of various results from hedging, basis risk must also be considered. The basis risk is reflected by the standard error of the forecast (SEF) for the particular bison type and contracting period used. Assuming the prices move together and basis is predictable, equation (13) can be used to help the hedger calculate the bison cash price equivalent of a particular futures contract price during the months prior to the hedge initiation. The SEF statistic then allows the hedger to calculate cash price confidence intervals associated with a particular hedge.

4.2 Cointegration Analysis

OLS cross-hedging models assume variables are stationary. Time series data are considered stationary if its properties, such as the mean and variance, are constant throughout time. Non-stationary OLS model's point estimates are unbiased and consistent, but their standard errors will be inconsistent, and the hypothesis test statistics and confidence intervals will not hold. To determine if the data are stationary, three variations of the Dickey-Fuller unit root test were preformed on all cash and futures time series. Further detail on the model tests can be found in Section 2.4, equations (8), (9), and (10).

4.2.1 Correcting for Autocorrelation

Excess autocorrelation causes non-stationarity and is a typical concern when dealing with time series data. Autocorrelation occurs when model errors are not independent, for example an error occurring at period t influences the error in the next period $t+1$. If the Dickey-Fuller test shows evidence of a unit root in the data series, first differencing the data is a proper procedure to transform the data. First differencing the data transforms the left and right hand side variables into differences. In the presence of a unit root, autoregressive models can also be used to address heteroskedasticity. To address the possibility of first order autocorrelation, the autoregressive function, ARCH(1), is estimated.

Adjusting cross-hedging models for autocorrelation is widely debated in literature (Elam 1991, Copeland and Zhu, 2006). Therefore, the proper methodology is dependent on the user's goal. If a user were primarily concerned with hypothesis testing, an autoregressive model with more efficient estimates would be preferable. However, a hedger who aims to reduce hedging risk may want to consider using an

OLS method. When analyzing cattle markets, Elam (1991) finds that autoregressive models can also increase hedging risk. Elam (1991) indicates that the higher the autocorrelation in the residuals and the shorter the length of time a hedge is held, the better autoregressive models are at reducing hedging risk. The author suggests that practicing cattle hedgers that hold positions for longer than one month are better off using a price level OLS method because it provides the least hedging risk.

Both OLS and autoregressive models are used in this analysis.

4.3 Data Sources

Average monthly bison carcass prices come from the USDA's Monthly Bison Report released on/near the 10th of each month. The report provides prior month wholesale/distributor market information on carcasses and sub-primal cuts. Depending on market activity, seven to nine contributors from across the United States report what they are paying for carcass weights. The recorded prices do not include any prices of carcasses sold directly to a customer (Dineen 2008). The report provides prices for culled bison bulls and heifers, and further segments the groups by age; animals under the age of 30 months are classified as young, while animals older than 30 months are classified as aged. The four subcategories contain recorded monthly carcass quantities and cwt. carcass prices (high, low and average). The young bison bull (under 30 months) most closely fits the live cattle futures contract specifications. In order to most accurately compare prices, bison carcass prices are converted into live weight prices, using a 57% average dressing yield.

The nearby contract for live cattle is used against bison prices to assess hedging windows. Monthly averages, computed with daily settlement prices, are considered because bison prices are provided as monthly averages. The nearby month refers to the contract month with an expiration date closest to the current date. The front month is generally the most liquid of futures contracts in addition to having the smallest spread between the futures price and the spot price on the underlying commodity.

4.3.1 Summary of Data

Table 4.1 shows estimated live weight prices for young bison. The weighted average price is computed by taking the average price of bulls and heifers and weighting the averages by the number of bulls and heifers slaughtered each month. The average number of heifers slaughtered is nearly 40% less than bulls, with the total average bison slaughtered per month at about 2,617 head.

Table 4.1 Summary of Monthly Bison Statistics (6/2004-3/2014)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Average Bull Price ($/cwt)	118	152.106	51.644	90.071	227.111
Average Heifer Price ($/cwt)	118	144.217	52.171	81.425	220.356
Weighted Average Price ($/cwt)	118	149.042	51.620	88.190	223.011
Head of Bull to Slaughter	118	1603.678	429.853	769	2792
Head of Heifer to Slaughter	118	1012.983	358.911	179	2206
Total Bison Head to Slaughter	118	2616.661	550.048	1120	3927

Table 4.2 summarizes nearby future month settle prices. Average live cattle prices and their standard deviations are much lower than those for bison. Table 4.3 describes the statistics of the bison basis using the live cattle futures contract. The coefficient of variation (CV) for bison prices is nearly twice as large as the CV for live cattle futures prices, 34.6% and 17.0% respectively.

Table 4.2 Summary of Live Cattle Nearby Prices (6/2004-3/2014)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Average Monthly Settle Price ($/cwt)	118	100.622	17.132	76.873	144.637

As discussed in Chapter 2, basis risk is an important consideration for hedgers. Across the three bison groups, standard deviation of the basis is lower than the standard deviation of bison price. However, the range of bison basis is over $100.00 across the groups, suggesting the bison industry has not yet reached a price equilibrium.

Table 4.3 Summary of Monthly Bison Basis Statistics Using the Nearby Live Cattle Futures Contract (6/2004-3/2014)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Bison Bull Basis ($/cwt)	118	51.484	37.080	1.451	107.417
Bison Heifer Basis ($/cwt)	118	43.595	37.667	-6.902	103.498
Weighted Average Bison Basis ($/cwt)	118	48.420	37.075	-2.048	105.454

Table 4.4 shows the total quantity slaughtered and the weighted average price of bison for each calendar year. With the exception of 2013, the bison price has continued to increase throughout the period, with the biggest jump in price of $57/cwt. in 2011. The number of bison slaughtered increased from the period of 2005-2009, decreased from 2009-2011, and then increased again in 2012 and 2013. The decrease in slaughtered bison is due to ranchers holding back animals to expand their herds (Hansen and Geisler 2012).

Table 4.4 Yearly Live Bison Price and Quantity (2005-2013)

Year	Total Head Slaughtered	Average Price $/cwt
2005	25,121	91.77984
2006	27,787	98.84989
2007	30,314	105.3318
2008	32,974	127.6636
2009	37,337	131.6512
2010	36,382	154.1555
2011	29,655	211.468
2012	32,255	220.1103
2013	36,297	218.0824

Table 4.5 shows the yearly Canadian exports of bison, direct to slaughter, to the U.S[1]. During the period of 2005-2010 there is a general increase in imports of bison, yearly live bison slaughtered in the U.S., and the average bison price. This shows that the increase in bison price is likely due to strong demand drivers rather than restricting supply to increase price. Bison is an emerging market and as people learn about bison as a protein substitute, consumer knowledge drives the increase in demand.

[1] Obtained through a personal interaction on June 20, 2014 with Richard Tanger, an Assistant to the Director of the United States Department of Agriculture's Agricultural Marketing Service

Table 4.5 Yearly Canadian Exports of Bison to the U.S. (2000-2010)

Year	Direct to Slaughter
2000	2,582
2001	1,853
2002	1,480
2003	579
2005	2,253
2006	9,912
2007	16,178
2008	18,644
2009	17,237
2010	14,542

Table 4.6 is a correlation matrix of the bison and live cattle prices. The bison bull price and the nearby live cattle futures prices have the strongest correlation of 0.8961. The squared correlation coefficient shows 80.30% of the change in bison bull prices is associated with the change in live cattle futures prices.

Table 4.6 Correlations for Average Monthly Bison and Live Cattle Futures Prices ($/cwt) (6/2004-3/2014)

	Bison Bull	Bison Heifer	Average Bison	Nearby Cattle Futures
Bison Bull	1			
Bison Heifer	0.9989	1		
Average Bison	0.9997	0.9994	1	
Nearby Cattle Futures	0.8961	0.8931	0.8953	1

Table 4.7 is a correlation matrix of the first difference data. The first difference data series represents the changes from one period to the next. There is a considerable discrepancy between correlations of the prices levels found in Table 4.6 and price differences found in Table 4.7. This suggests the data is not stationary and may require more sophisticated forecasting models, such as ARCH(1), to provide efficient estimates.

Table 4.7 First- Difference Correlations for Average Monthly Bison and Live Cattle Futures Prices ($/cwt) (6/2004-3/2014)

	Bison Bull	Bison Heifer	Average Bison	Nearby Cattle Futures
Bison Bull	1			
Bison Heifer	0.6577	1		
Average Bison	0.8888	0.7958	1	
Nearby Cattle Futures	-0.0018	0.0085	-0.0334	1

Chapter 5 – Empirical Results

5.1 OLS Hedge Ratio Equations

Cross-hedge ratios for bison bull and average bison prices are reported in Table 5.1. The optimal hedge ratio can be explained as the proportion of the cash position considered in a futures hedge. The R-statistic and the mean standard error of the forecast (SEF) are also reported. The hedge ratios are very similar between the two bison groups. Hedge ratios, reported as the slope coefficients, reveal a great deal of seasonality and longer hedging windows smooth the seasonality in hedge ratios. Seasonality and similarity between the bison groups is further illustrated in Figures 5.1 and 5.2.

The R-statistics for the OLS estimations range from 0.771 to 0.878. As the hedging window increases in length, the R-squared values typically decrease, with the exception of February and April contract months. Lower R-squared values indicate that longer hedge windows may not be as efficient. SEF (mean) values typically decrease with longer hedging windows. The one month bison bull October hedge ratio equation has the highest R-squared and lowest SEF value, suggesting it is the best model to follow when hedging bison using live cattle contracts. Figure 5.3 illustrates the one month bison bull October linear regression model with the SEF confidence interval, where it is expected that two-thirds of the forecasted values falls within the SEF confidence interval. Although the SEF increases with distance from the independent variable mean, only the SEF at the mean is considered in Figure 5.3 and Table 5.1. Acceptable R-squared and SEF values will vary greatly across firm managers. For example, a large variance around the estimated regression relationship may not preclude hedging if the manager expects it is likely there will be an adverse price change in cash prices.

The SEF values, representing basis risk, are consistently lower than the bison bull and average bison cash price standard deviations, representing cash price risk. Although this suggests that hedging is favorable for bison producers, autocorrelation must be tested in order to confirm that statistics are robust and parameters are accurate.

Table 5.1 OLS Bison Hedge Ratio Equations for Bison Bulls and Average Bison (6/2004-3/2014)

Hedge Windows	Bison Bulls			Average Bison		
	1 Month	**3 Month**	**6 Month**	**1 Month**	**3 Month**	**6 Month**
February						
Intercept	-100.217	-113.005	-129.442	-104.429	-116.359	-132.601
Slope	2.480	2.617	2.795	2.481	2.614	2.795
R^2	0.772	0.791	0.820	0.771	0.800	0.820
SEF (mean)	26.187	24.057	22.223	26.271	23.780	22.180
N	20	40	70	20	40	70
April						
Intercept	-87.464	-92.752	-104.699	-90.241	-96.281	-108.161
Slope	2.326	2.391	2.528	2.318	2.389	2.527
R^2	0.801	0.785	0.797	0.7995	0.784	0.799
SEF (mean)	24.552	24.805	23.761	24.563	24.844	23.657
N	20	40	67	20	40	67
June						
Intercept	-143.131	-137.253	-138.395	-146.660	-140.106	-141.619
Slope	2.982	2.886	2.892	2.988	2.882	2.890
R^2	0.820	0.813	0.798	0.820	0.810	0.796
SEF (mean)	22.509	22.211	22.758	22.692	22.394	22.877
N	18	36	63	18	36	63
August						
Intercept	-168.519	-146.354	-136.386	-172.455	-150.150	-139.650
Slope	3.284	3.050	2.901	3.304	3.063	2.904
R^2	0.848	0.833	0.804	0.852	0.832	0.8000
SEF (mean)	20.882	20.928	22.408	20.703	21.083	22.739
N	20	36	63	20	36	63
October						
Intercept	-163.845	-161.922	-142.731	-167.519	-165.531	-146.735
Slope	3.140	3.167	2.976	3.152	3.181	2.989
R^2	0.878	0.854	0.835	0.878	0.855	0.833
SEF (mean)	18.77	19.942	20.595	18.845	19.944	20.825
N	20	40	63	20	40	63
December						
Intercept	-128.832	-144.495	-134.194	-131.431	-147.431	-137.810
Slope	2.787	2.944	2.902	2.780	2.945	2.911
R^2	0.828	0.850	0.831	0.837	0.854	0.832
SEF (mean)	22.706	20.484	20.87	21.945	20.153	20.867
N	20	40	63	20	40	63

Figure 5.1 Bison Bull OLS Hedge Ratios by Hedging Window

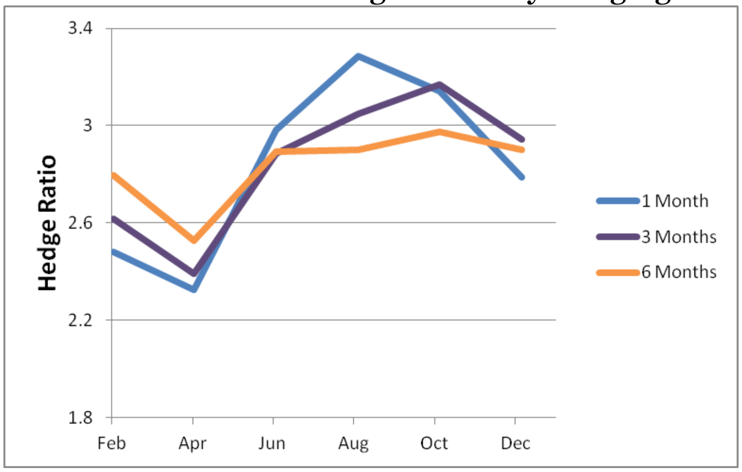


Figure 5.2 Average Bison OLS Hedge Ratios by Hedging Window

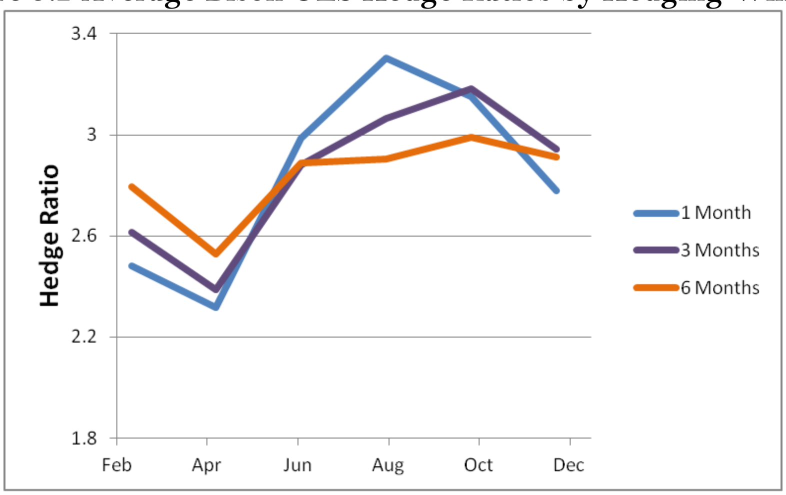
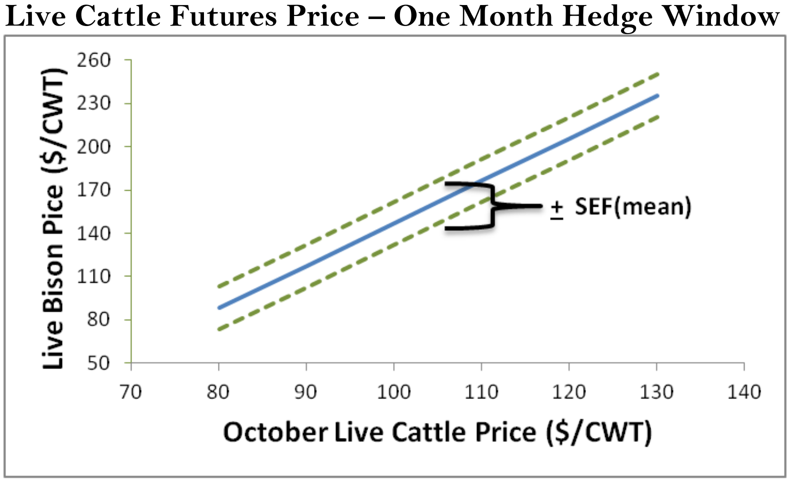


Figure 5.3 OLS Regression of Bison Bull Price and October Live Cattle Futures Price – One Month Hedge Window



5.2 Dickey-Fuller Results

The Dickey-Fuller test is based on three regression forms, as discussed in Section 2.4: one with no drift and no trend, one with a drift and no trend, and one with a drift and a trend. It is important to test all three regressions because they can produce conflicting results. In the case of inconsistency in the models, the unit root test is confirmed by adopting an augmented Dickey-Fuller test.

All three regression forms found consistent results for each data series. The computed Dickey-Fuller test-statistics (T_{au}) were greater than the critical values at the 1%, 5%, and 10% significance level, thus the null hypothesis of the presence of a unit root cannot be rejected. Table 5.2 presents the results in greater detail.

Table 5.2 Dickey Fuller Unit Root Tests --
Average Monthly Futures and Bison Cash Prices (6/2004-3/2014)

	with No Drift and No Trend				
	T_{au}		1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	1.628		-2.598	-1.950	-1.611
Average Bison Price	4.462		-2.598	-1.950	-1.611
Bull Price	4.67		-2.598	-1.950	-1.611
	with a Drift and No Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	0.423	0.9823	-3.504	-2.889	-2.579
Average Bison Price	0.191	0.9717	-3.504	-2.889	-2.579
Bull Price	0.107	0.9965	-3.504	-2.889	-2.579
	with a Drift and a Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-1.564	0.806	-4.034	-3.448	-3.148
Average Bison Price	-1.324	0.882	-4.034	-3.448	-3.148
Bull Price	-1.215	0.907	-4.034	-3.448	-3.148

5.3 Correcting for Unit Roots

To correct for the presence of a unit root the first differenced data and AR(1) models are analyzed. All Dickey-Fuller regressions show that first-differencing removed the unit-root in the data sets. The computed test-statistics (T_{au}) are consistently less than the critical values, thus the null of the presence of a unit root is rejected at the 1% significance level.

Table 5.3 Dickey Fuller Unit Root Tests – First Differenced Average Monthly Futures and Bison Cash Prices (6/2004-3/2014)

	with No Drift and No Trend				
	T_{au}		1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-7.940		-2.598	-1.950	-1.611
Average Bison Price	-6.535		-2.598	-1.950	-1.611
Bull Price	-6.201		-2.598	-1.950	-1.611
	with a Drift and No Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-8.057	<0.0001	-3.505	-2.889	-2.579
Average Bison Price	-7.400	<0.0001	-3.505	-2.889	-2.579
Bull Price	-7.025	<0.0001	-3.505	-2.889	-2.579
	with a Drift and a Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-8.121	<0.0001	-4.035	-3.448	-3.148
Average Bison Price	-7.377	<0.0001	-4.035	-3.448	-3.148
Bull Price	-7.003	<0.0001	-4.035	-3.448	-3.148

5.4 Comparing Hedge Ratios

Equation 13 is used to regress bison bull and average bison prices on live cattle futures. The OLS equations display a great deal of seasonality. However autocorrelation proved to be present in the data series, therefore corrective models must be assessed. In the following sections results for first-differenced and autoregressive models are compared to OLS results.

Table 5.4 and 5.5 report bison bull and average bison hedge ratio approaches used in this analysis. The standard error statistic is reported as well. This statistic can be used to construct a confidence interval for the hedge ratios, illustrated in Figures 5.4 and 5.5. Hedge ratios from first-differenced data are consistently insignificant at the 10% level. Additionally, all variation is taken out by first-differencing the data resulting in first differenced hedge ratios that are much too low, making cross-hedging unfeasible due to the fact that hedgers do not have enough bison to hedge a full contract.

The majority of the autoregressive hedge ratios are not valid because the variance equation does not follow first order autocorrelation. The AR(1) model is only valid if the ARCH term is statistically significant, concluding that the variance equation has first order autocorrelation. The autoregressive hedge ratios are inconsistent in comparison to the OLS ratios, sometimes larger and sometimes smaller. Figures 5.6 and 5.7 illustrate the hedge ratio comparisons. Following the findings of Elam (1991), which suggest that OLS hedge ratios will provide less basis risk than autocorrected ratios, autoregressive procedures over-estimate and under-estimate hedge ratios in different hedge windows. When using OLS models, the presence of autocorrelation is a concern if statistical testing is necessary. However, practicing hedgers who plan to hold a hedge for longer than one month will receive greater risk reduction by using OLS ratios (Elam, 1991). OLS hedge ratio error coefficients range from 0.157-0.354 and AR(1) error coefficients range from 0.048-0.460.

Table 5.4 Bison Bull Hedge Ratios, Monthly Data (6/2004-3/2014)

	One Month Hedge			Three Month Hedge			Six Month Hedge		
	AR(1)	**OLS**	**1^{st}-Diff**	**AR(1)**	**OLS**	**1^{st}-Diff**	**AR(1)**	**OLS**	**1^{st}-Diff**
February	2.117**	2.480	-0.079*	3.181	2.617	-0.026*	3.134	2.795	0.018*
S.E.	0.201	0.317	0.123	0.118	0.215	0.130	0.081	0.159	0.114
R-Squared		0.772	0.018		0.797	0.001		0.820	<0.001
N	20			40			70		
April	2.322**	2.326	0.017*	1.896	2.391	-0.038*	3.115	2.528	-0.018*
S.E.	0.260	0.273	0.219	0.048	0.203	0.132	0.086	0.158	0.121
R-Squared		0.801	<0.001		0.785	0.002		0.797	<0.001
N	20			40			67		
June	2.982**	2.982	0.021*	2.823**	2.886	0.025*	2.672**	2.892	0.006*
S.E.	0.460	0.351	0.084	0.261	0.237	0.106	0.184	0.186	0.082
R-Squared		0.819	0.004		0.813	0.002		0.798	<0.001
N	18			36			63		
August	3.192**	3.284	-0.065*	3.036**	3.050	-0.021*	2.927**	2.901	-0.037*
S.E.	0.194	0.328	0.133	0.294	0.234	0.064	0.212	0.183	0.079
R-Squared		0.8479	0.015		0.833	0.003		0.804	0.004
N	20		18	36			63		
October	3.115**	3.140	0.097*	3.136**	3.167	-0.005*	2.978	2.976	-0.015*
S.E.	0.251	0.276	0.426	0.160	0.212	0.185	0.152	0.170	0.077
R-Squared		0.878	0.003		0.854	<0.001		0.835	<0.001
N	20			40		36	63		
December	2.996**	2.787	0.100*	3.175**	2.944	0.091*	3.049**	2.902	0.022*
S.E.	0.226	0.300	0.224	0.159	0.201	0.180	0.155	0.168	0.093
R-Squared		0.828	0.110		0.850	0.007		0.831	0.001
N	20			40			63		

*statistic is not significant at the 10% level
**ARCH variance statistic is not significant at the 10% level

Table 5.5 Average Bison Hedge Ratios, Monthly Data (6/2004-3/2014)

	One Month Hedge			Three Month Hedge			Six Month Hedge		
	AR(1)	OLS	1st-Diff	AR(1)	OLS	1st-Diff	AR(1)	OLS	1st-Diff
February	2.105**	2.481	-0.007*	2.649	2.614	0.012*	3.093	2.795	0.038*
S.E.	0.190	0.318	0.161	0.129	0.212	0.143	0.078	0.159	0.117
R-Squared		0.771	<0.001		0.800	<0.001		0.820	0.002
N	20			40			70		
April	2.318**	2.318	0.118*	1.900	2.389	0.038*	3.082	2.527	0.008*
S.E.	0.265	0.274	0.211	0.054	0.203	0.141	0.086	0.157	0.124
R-Squared		0.800	0.017		0.784	0.002		0.799	<0.001
N	20			40			67		
June	2.990**	2.988	-0.104*	2.811**	2.882	0.004*	2.620**	2.890	-0.017*
S.E.	0.457	0.354	0.077	0.263	0.239	0.103	0.179	0.187	0.088
R-Squared		0.817	0.1026		0.810	<0.001		0.796	<0.001
N	18			36			63		
August	3.203**	3.304	-0.049*	3.032**	3.063	-0.087*	2.893**	2.904	-0.063*
S.E.	0.218	0.325	0.152	0.293	0.236	0.066	0.217	0.186	0.079
R-Squared		0.852	0.006		0.832	0.048		0.800	0.010
N	20		18	36			63		
October	3.124**	3.152	-0.105*	3.133**	3.181	-0.095*	2.964	2.989	-0.072*
S.E.	0.276	0.277	0.402	0.167	0.212	0.179	0.155	0.172	0.075
R-Squared		0.878	0.004		0.855	0.008		0.833	0.015
N	20			40		36	63		
December	2.925**	2.780	0.108*	3.139**	2.945	0.057*	3.026**	2.911	-0.037*
S.E.	0.213	0.289	0.238	0.172	0.198	0.180	0.161	0.168	0.095
R-Squared		0.837	0.011		0.854	0.003		0.832	0.003
N	20			40			63		

*statistic is not significant at the 10% level
**ARCH variance statistic is not significant at the 10% level

Figure 5.4 Bison Bull OLS Hedge Ratio and Standard Error-3 Month Hedge Window

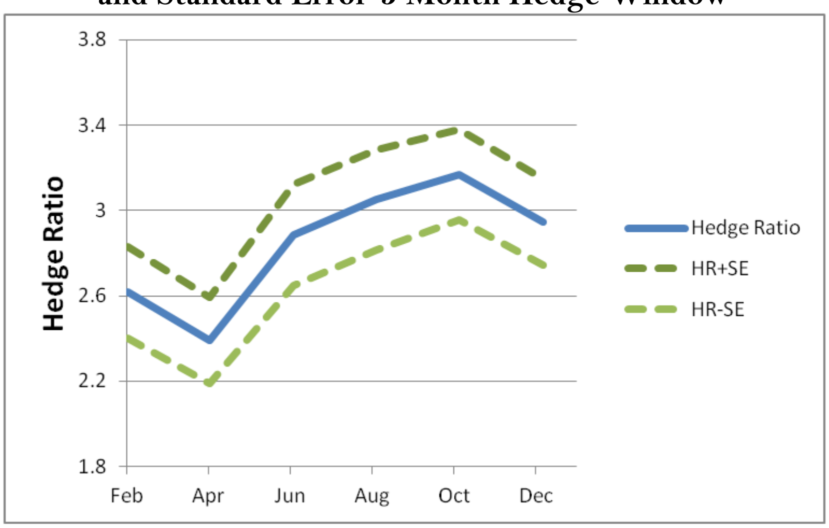


Figure 5.5 Average Bison AR(1) Hedge Ratio and Standard Error-6 Month Hedge Window

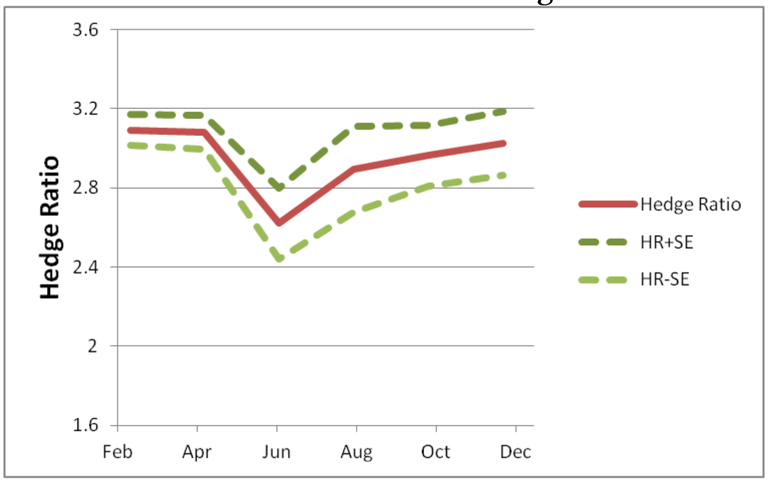


Figure 5.6 Bison Bull OLS and AR(1) Hedge Ratios-3 Month Hedge Window

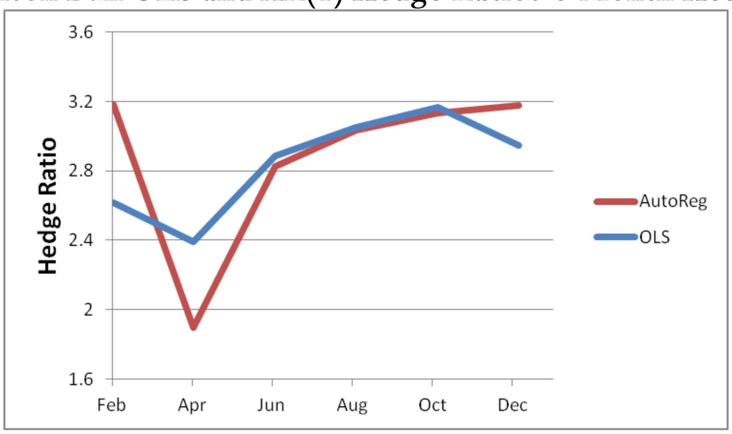
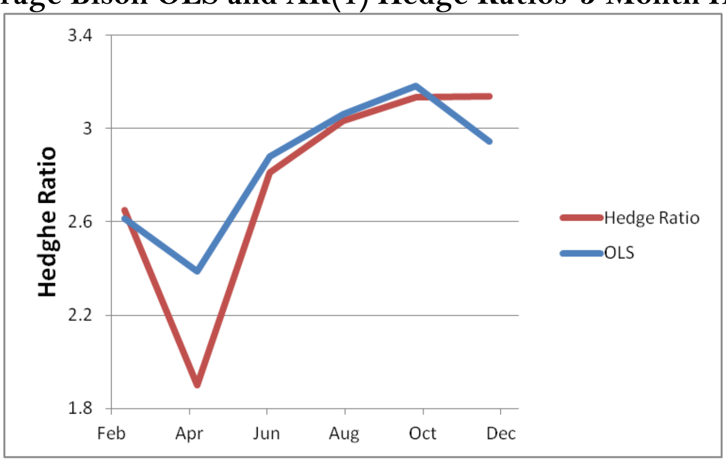


Figure 5.7 Average Bison OLS and AR(1) Hedge Ratios-3 Month Hedge Window



5.5 Cross-Hedging Example

In June of a typical year, if a bison producer makes a large sales commitment and wants to lock in a favorable selling price on live bison bulls for sale in September, the producer would use the 3-month October live cattle contract window to hedge. Assume the producer is selling 60 bison bulls and the current October live cattle futures price is $138.00/cwt. Using the OLS 3-month October bison bull hedge equation, the bison producer can convert the futures price of $138.00 into an expected live bison bull price of $275.124/cwt. [-161.922+3.167(138)].

The bison producer must take a position in the futures market that is 3.167 times larger than the cash position in order to equalize the gains and losses. Using the ideal bison bull live weight of 1130 lbs. per live bull, the bison producer must hedge approximately 214,722 lbs. [1130*60*3.167] using the live cattle contracts. Each live cattle contract is 40,000 pounds, therefore the bison producer must sell five [214,700/40,000] October live cattle futures contracts in June.

Selling five contracts of October live cattle contracts at $138.00 can establish the approximate selling price of $275.124 for 214,722 pounds of live bison, even though the actual sale of bison bulls would not take place until sometime in September or early October. The bison producer would expect the actual cash price to be within ± $20 of the estimated price approximately two-thirds of the time. A 95% confidence interval shows that a bison producer can expect the actual cash price to be within approximately + $40 of the estimated price, ranging from $236-$314. As the bison producer sells his bison bulls in the cash market, a futures contract (40,000 pounds) should be sold for each 12,600 lbs. of bison bulls sold in the market.

5.6 Summary

Excessive autocorrelation weakens the case for using OLS techniques for cross-hedging bison with live cattle futures. In addition, first-differencing the data confirms that bison and live cattle prices do not move in a predictable proportional pattern. AR(1) models have few appropriate hedging windows, and following theory set by Elam (1991) autoregressive models are not necessarily the most risk-minimizing approach for active hedgers. The previous section illustrates that predicting an appropriate cross-hedge ratio for bison with a high level is a difficult task.

The October contract models have the highest calculated goodness of fit measures across all three hedge durations, but Section 5.5 shows that the achieved cash price falls within a large price range. The findings of Chapter 5 do not preclude hedging; however managers who intend to hedge bison with live cattle contracts must be comfortable with large levels of basis risk. Levels of risk aversion and price expectations will determine the usefulness of cross-hedging to a particular manager.

Chapter 6 - Reevaluating the Data

Chapter 5 shows that basis risk is an important consideration for bison producers looking to cross-hedge their animals with the live cattle contracts. In this section the data is reevaluated in an attempt to construct a model with less basis risk.

6.1 Identifying a Break-Date

Figure 6.1 documents the price data used in the analysis. In October 2011 bison prices leveled, indicating the bison market reaching equilibrium. Figure 6.2 shows prices from October 2011 to the end of the data set. The time period of Figure 6.2 is considered in order to evaluate if recent prices provide less basis risk when hedging bison with live cattle futures.

Figure 6.1 Monthly Average Prices of Live Bison and Live Cattle Futures Prices ($/cwt) (6/2004-3/2014)

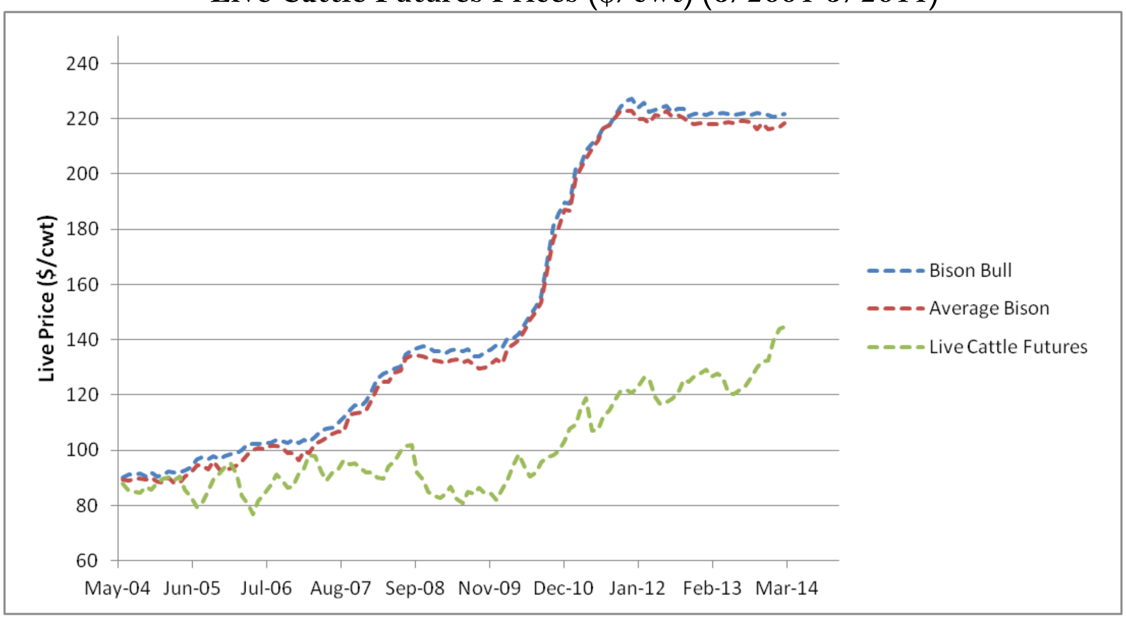
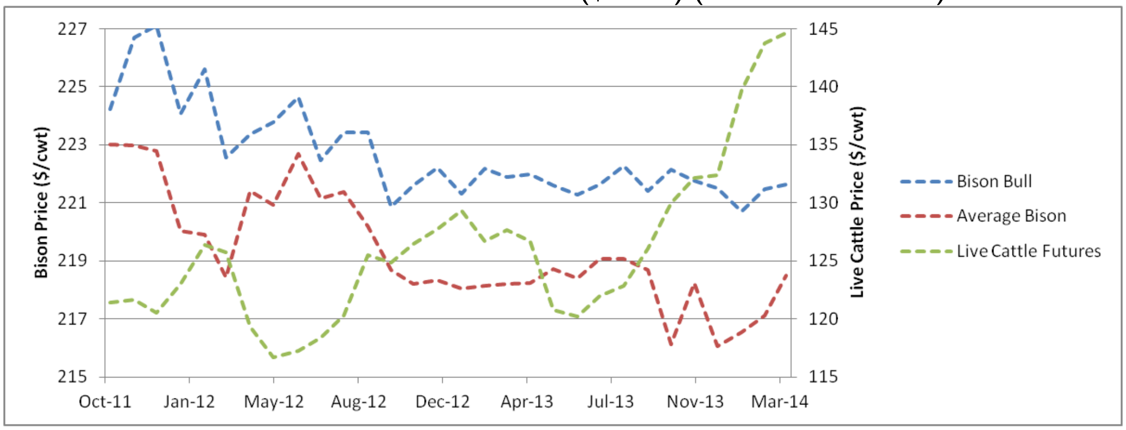


Figure 6.2 Monthly Average Prices of Live Bison and Live Cattle Futures Prices ($/cwt) (10/2011-3/2014)



First, a Chow test is performed in order to confirm a structural break in the data. The model with breaks is as follows:

(14) $C_t = \propto + \beta F_t + \delta d_t + \gamma d_t F_t + u_t$

where C_t and F_t represent the monthly average bison and live cattle futures prices, respectively, at time, *t*. Variable d_t is a dummy variable defined as d=1 if t is greater than October 2011, and $d_t F_t$ is used to test for changes in the break-date data. When interpreting the coefficients, δ and γ represent the change in intercept and slope of the structural break data.

The Chow test calls for a joint F-test on δ and γ coefficients after equation 14 is estimated. The joint F-test confirms that the time period of October 2011 to March 2014 is significantly different from the entire data set at the 1% significance level. This conclusion suggests a cross-hedge analysis on the break-date data may provide insight on a cross hedge with less basis risk than found in previous models.

6.2 Summary of Break-Date Data

Before beginning the cross-hedge analysis, the data from October 2011 to March 2014 is examined. Table 6.1 shows estimated live weight prices for young bison. The weighted average price is computed by taking the average price of bulls and heifers and weighting the averages by the number of bulls and heifers slaughtered each month. The break-date data has an average bull price and weighted average bison price that is about

$70.00 higher than the entire data set seen in Table 4.1. Bison price standard deviations are also about $50.00 less in the break-date series. The average number of bison slaughtered per month is similar in Tables 6.1 and 4.1.

Table 6.1 Summary of Break-Date Monthly Bison Statistics (10/2011-3/2014)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Average Bull Price ($/cwt)	30	222.692	1.638	220.715	227.111
Weighted Average Price ($/cwt)	30	219.308	1.968	216.051	223.011
Head of Bull	30	1653.067	361.338	1019	2574
Head of Heifer	30	1177.267	272.805	680	1995
Total Bison Head	30	2830.333	410.394	2195	3520

Table 6.2 summarizes nearby future month settle prices. The average live cattle standard deviation is much higher than the standard deviation in bison, which is much different than that found in Section 4.3.1. This indicates that for the break-date series, live cattle futures prices exhibit more price variability than bison prices, thus suggesting that the cross-hedging basis may hold more risk than bison cash prices.

Table 6.2 Summary of Break-Date Live Cattle Nearby Prices (10/2011-3/2014)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Average Monthly Settle Price ($/cwt)	30	126.008	7.021	116.685	144.637

Table 6.3 describes the statistics of the bison basis using the live cattle futures contract. Bison prices in Table 6.1 have significantly smaller standard deviations than their basis counterparts found in Table 6.3: 95% of weighted average bison prices fall in a $8.00 price window, and 95% of weighted average bison basis values fall in a $34.00 price window. These results suggest that the bison industry has reached a price equilibrium that is much less volatile than the live cattle futures market, making cross-hedging less attractive for bison producers.

Table 6.3 Summary of Break-Date Monthly Bison Basis Statistics Using the Nearby Live Cattle Futures Contract (10/2011-3/2014)

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
Bison Bull Basis ($/cwt)	30	96.684	7.920	77.008	107.417
Weighted Average Bison Basis ($/cwt)	30	93.300	8.471	73.348	105.454

Table 6.4 is a correlation matrix of the break-date data. Bison prices and nearby live cattle futures prices exhibit negative correlations, deeming cross-hedging unfit in the normal process. A negative correlation between two variables means that as one variable increases the other decreases, and vice-versa. Cross-hedging is based on the theory that prices move together in time with a positive correlation, so when taking opposite positions in the cash and futures market gains and losses will be balanced. Average bison prices and nearby live cattle futures prices have a strong negative correlation of -0.6729. The squared correlation coefficient shows 45.30% of the change in bison bull prices is negatively associated with the change in live cattle futures prices. The negative correlation means that bison producers holding a long cash position require a long futures position when hedging. Although cross-hedging is still possible, the key question is whether or not it is desirable. This can be determined by assessing the R-squared value and the basis and bison price risk.

Table 6.4 Correlations for the Break-Date Average Monthly Bison and Live Cattle Futures Prices ($/cwt) (10/2011-3/2014)

	Bison Bull	**Average Bison**	**Nearby Cattle Futures**
Bison Bull	1		
Average Bison	0.8062	1	
Nearby Cattle Futures	-0.4673	-0.6729	1

Table 6.5 is a correlation matrix of the first difference data, analyzed in the case of non-stationarity in the break-date data series. Correlations of the first-difference prices are much less negative than the price level correlations found in Table 6.4. However, they both exhibit correlations that are very close to zero, suggesting price

changes in nearby live cattle futures prices have very little power to explain changes in bison prices.

Table 6.5 First- Difference for the Break-Date Correlations for Average Monthly Bison and Live Cattle Futures Prices ($/cwt) (10/2011-3/2014)

	Bison Bull	**Average Bison**	**Nearby Cattle Futures**
Bison Bull	1		
Average Bison	0.5372	1	
Nearby Cattle Futures	0.0071	-0.2089	1

6.3 Break-Date OLS Cross-Hedge Estimation

Since there is limited data in the break-date series, seasonality is not considered in the OLS cross-hedge analysis. The entire series is tested in the OLS cross-hedge analysis using the following estimation:

(15) $CP_{ij} = \alpha + \beta FP_i + u_i$

where CP_i is the average monthly price of bison group *j* during the break-date period *i* spanning from October 2011 to March 2014; FP_i is the monthly average of daily settlement prices for the nearby live cattle futures contract during break-date period *i*; and u_i is the error term.

The results from equation 15 can be found in Table 6.6. The negative correlations found in Table 6.4 are reflected in the negative slope coefficients found in Table 6.6. The slope coefficients can be interpreted as follows; if live cattle futures prices increase by $1.00, the model predicts that average bison prices will decrease by $0.189 and bison bull prices will decrease by $0.109.

Slope coefficients are meant to be used as the cross hedge-ratio. Negative slope coefficients warrant hedging by taking the same position on the futures market as the cash market, instead of the typical hedging approach of taking opposite positions in the cash and futures markets. Therefore, the results in Table 6.6 show producers can hedge their bison by taking long futures positions. However, the hedge ratios are very small which may make hedging infeasible. For example, the bison bull hedge ratio of -0.109

means bison producers take a hedging position equal to 10.9% of their bison bull pound weight. Futures contracts must be traded in integer values. Therefore in order for a bison producer to purchase one live cattle contracts he must have approximately 337,000 lbs. of live bulls to hedge. Using the ideal live weight of 1130 lbs. per live bull, a bison producer would need to hedge 325 bulls.

R-squared values in Table 6.6 are much lower than the R-squared values found when assessing the whole data set in Section 5.1, suggesting the break-date live cattle futures price does not explain bison prices as well as the whole data set. However, SEF values are much lower in the break-date OLS analysis, suggesting there is less basis risk. Acceptable R-squared and SEF values will vary greatly across managers, given different risk profiles and price expectations.

Table 6.6 Break-Date OLS Bison Hedge Ratio Equations for Bison Bulls and Average Bison Using Monthly Prices (10/2011-3/2014)

	Bison Bulls	Average Bison
Intercept	236.4302	243.069
Slope	-0.109	-0.189
R^2	0.218	0.453
SEF (mean)	1.474	1.481
N	30	30

6.4 Break-Date Dickey-Fuller Results

Dickey-Fuller tests are run on the break-date data series to check for the presence of a unit-root. The Dickey-Fuller results in Table 6.7 typically indicate the presence of a unit-root at the 10% confidence level. Yet, the average bison price and bull price series reject the null of the presence of a unit root at the 10% level when considering the Dickey-Fuller test with the presence of a drift and a trend. To check these results, an augmented Dickey-Fuller test is run with a drift, trend, and 1-lag value. The results, found in Table 6.7.1, confirm the presence of a unit root in all three data series at the 10% level.

Table 6.7 Break-Date Dickey Fuller Unit Root Tests --
Average Monthly Futures and Bison Cash Prices (10/2011-3/2014)

	with No Drift and No Trend				
	T_{au}		1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	1.504		-2.654	-1.950	-1.602
Average Bison Price	-0.667		-2.654	-1.950	-1.602
Bull Price	-0.386		-2.654	-1.950	-1.602
	with a Drift and No Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	0.517	0.9854	-3.723	-2.989	-2.625
Average Bison Price	-2.391	0.1444	-3.723	-2.989	-2.625
Bull Price	-2.277	0.1794	-3.723	-2.989	-2.625
	with a Drift and a Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-0.707	0.9727	-4.343	-3.584	-3.230
Average Bison Price	-3.249	0.0751	-4.343	-3.584	-3.230
Bull Price	-4.002	0.009	-4.343	-3.584	-3.230

Table 6.7.1 Break-Date Augmented Dickey Fuller Unit Root Test --
Average Monthly Futures and Bison Cash Prices (10/2011-3/2014)

	with a Drift and a Trend and 1 lag				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-1.729	0.7378	-4.352	-3.588	-3.233
Average Bison Price	-2.452	0.352	-4.352	-3.588	-3.233
Bull Price	-2.610	0.275	-4.352	-3.588	-3.233

6.5 Correcting for Unit Roots

To correct for the presence of a unit root, the first differenced data and AR(1) models are analyzed. All Dickey-Fuller regressions show first-differencing removed the unit-root in the data sets. The computed test-statistics (T_{au}) are consistently less than the critical values, thus the null of the presence of a unit root at the 1% significance level is rejected.

Table 6.8 Break-Date Dickey Fuller Unit Root Tests – First-Differenced Average Monthly Futures and Bison Cash Prices (10/2011-3/2014)

	with No Drift and No Trend				
	T_{au}		1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-3.649		-2.654	-1.950	-1.602
Average Bison Price	-7.640		-2.654	-1.950	-1.602
Bull Price	-7.337		-2.654	-1.950	-1.602
	with a Drift and No Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-3.765	0.003	-3.723	-2.989	-2.625
Average Bison Price	-7.646	<0.001	-3.723	-2.989	-2.625
Bull Price	-7.224	<0.001	-3.723	-2.989	-2.625
	with a Drift and a Trend				
	T_{au}	P_{au}	1% Critical Value	5% Critical Value	10% Critical Value
Nearby Futures Price	-4.004	0.009	-4.343	-3.584	-3.230
Average Bison Price	-7.529	<0.001	-4.343	-3.584	-3.230
Bull Price	-7.050	<0.001	-4.343	-3.584	-3.230

6.6 Comparing Break-Date Hedge Ratios

Equation 15 is used to regress bison bull and average bison prices on live cattle futures, representing the OLS equation in Table 6.9. First-difference and AR(1) models are also assessed due to the presence of autocorrelation in the data sets. Across all three methods, hedge ratios are much too low, making cross-hedging unfeasible because producers do not have enough bison to fill one futures contract. Both first-differenced hedge ratios are larger than OLS estimates, however the ratios are still much too small for cross-hedging to be considered.

Table 6.9 Break-Date Bison Bull and Average Bison Hedge Ratios, Monthly Data (10/2011-3/2014)

	Bison Bulls			Average Bison		
	AR(1)	**OLS**	**1st-Diff**	**AR(1)**	**OLS**	**1st-Diff**
Hedge Ratio	-0.017*	-0.109	0.003*	-0.293**	-0.189	-0.098
S.E.	0.021	0.039	0.090	0.033	0.039	0.090
R-Squared		0.218	<0.001		0.453	0.044
N	30			30		

*statistic is not significant at the 10% level
**ARCH variance statistic is not significant at the 10% level

Chapter 7 – Conclusions

Three main objectives were addressed in this research. The first objective was to analyze the bison industry across time, space, and product form. The second objective was to implement existing cross-hedge research techniques to the bison market. The final objective was to illustrate how estimated cross-hedge relationships are applied using a practical example.

7.1 Examining the Bison Market

Bison are primarily produced in the Midwest and Western United States. The breeding season is known to occur as early as April to as late as July, with an average span of two months. The majority of bison meat sold in the retail market is grain-finished for 90-100 days before slaughter, with grain supplements during times of low plant growth. Bison are typically slaughtered between the ages of 18-30 months.

The data used in the Chapter 5 analysis indicates that much variability existed in in bison prices over the 9-year period for which data is available. Weighted average bison prices range from a low of $88 to a high of $223. This indicats that a tool for managing bison price risk would be greatly beneficial to bison producers. However, the data used in Chapter 6 indicates very limited price variability in bison prices over the 2.5-year time span. Weighted average bison prices range from a low of $216 to a high of $223. Live cattle futures prices show much more price variability in the same 2.5-year time span, suggesting that bison producers will face more price risk if they choose to hedge.

7.2 Cross-Hedge Analysis

To address the second objective of research, cross-hedging ratios for bison bulls and average bison prices were analyzed. Each live cattle futures contract was analyzed with different hedge windows in order to find the most suitable seasonal period for cross-hedging. The October and December OLS estimates had the highest R-squared values, with shorter hedge windows of one and three months preferable to a six month hedge period. However, the large degree of autocorrelation in the data was a concern. First-differenced cross-hedge estimates proved to be ineffective with extremely low cross-hedge ratios and R-squared values. Autoregressive estimates only proved to be appropriate in a few instances, further weakening the case for cross hedging.

In Chapter 6, prices over the past two and a half years were analyzed. OLS cross-hedge estimates for average bison and bison bulls have negative slope coefficients; meaning cross-hedgers must take the same position on the cash and futures markets. Therefore, bison producers hedge their bison by taking long positions in the live cattle futures market. Since hedge ratios are very small, an exceptionally large volume of bison must be available in order to hedge. Large volume requirements may be unrealistic for many bison producers, making hedging infeasible. The basis risk is also much larger than the bison cash price risk over the two and a half year period. The standard deviation of the basis is around $8.00 for both bison bulls and average bison prices, while the standard deviation of bison prices is about $2.00 for both groups. With basis risk much greater than cash price risk, the break-date series shows that hedging bison would produce more risk than choosing not to hedge.

7.3 Implications of the Results

Although this research did not provide evidence that cross-hedging reduces the price risk for bison producers, cross-hedging may be plausible in the future. The bison market is still evolving, illustrated by the stair-step pattern in prices seen in Figure 6.1. Over the past nine years marketing schemes have propelled consumer knowledge of bison. The results in Chapter 5 reflect consumer behavior very early in the bison marketing cycle causing dramatic demand shifts that increased bison prices in short periods of time. Live cattle is already an established market, so prices reflect many supply and demand factors, such as the production cycle, input costs, and the marketing cycle. As bison becomes a better known commodity, consumer knowledge will play a lesser role in prices, and supply and demand drivers may assimilate to those found in live cattle. If price drivers align, cross-hedging using the live cattle futures contract may be feasible in the future.

Looking at the past two and a half years, Figure 6.2 shows a lull in bison prices. This time period also shows negative correlations between bison and live cattle futures prices. Although this is unusual, it is not unprecedented. It is unusual because it is expected that bison and beef are substitutes with similar factors driving prices.

However, negative correlations are not unprecedented because the bison industry is still very young and may be on a different marketing cycle. Emerging markets do not obey standard pricing paradigms because there is a lack of complete market integration. Emerging markets are dynamic and the lull in bison prices could be due to the fact that bison is reaching a point where demand and supply dynamics are changing, such as supply meeting or even outstripping demand as suggested by Hansen and Geisler (2012). When the bison market becomes more established, its marketing cycle may eventually sync with live cattle.

7.4 Suggestions for Further Research

There is limited financial literature written on the bison market. Bison is very new to the retail meat industry, and it would be interesting to examine the emerging market's effect on bison price. Looking at the price elasticity of bison over time could also help to better understand consumer behavior. As the market evolves, bison may eventually become a superior good whose price behaves similarly to beef. However, it will likely take years for the market to evolve to the point where bison price behavior approximates what is seen in the live cattle market.

It would also be interesting to see if it is possible to cross-hedge bison with other protein products, such as lean hogs. Although bison does not fit the lean hog future specifications as closely as beef, underlying supply and demand factors may be similar.

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