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Analyzing Market Dynamics: Effects on Quality Grade Premiums and Discounts for Alfalfa Hay

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ANALYZING MARKET DYNAMICS: EFFECTS ON QUALITY GRADE

PREMIUMS AND DISCOUNTS FOR ALFALFA HAY

by

Colby Wilkins

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ABSTRACT

Analyzing Market Dynamics: Effects on Quality Grade Premiums

And Discounts for Alfalfa Hay

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This paper investigates the impact of market strength on the premiums and discounts of prices received associated with varying qualities of alfalfa hay. Previous research has primarily concentrated on evaluating the impact of attributes of hay itself on the price received. This study employs ordinary least squares linear regression and visual data representations to analyze the effects of market strength on the premiums and discounts received associated with hay quality. The findings indicate during periods of relatively high average prices of alfalfa hay, there is no significant impact on the average premiums and discounts received. Conversely, during periods of relatively low average prices there are statistically significant variations in the premiums and discounts across quality grades of alfalfa hay. These insights can enhance the decision-making process for alfalfa hay producers by elucidating the effect of average market strength on received prices, thereby influencing their production practices.

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PUBLIC ABSTRACT

Analyzing Market Dynamics: Effects on Quality Grade
Premiums And Discounts for Alfalfa Hay

Colby Wilkins

This paper looks at how market strength affects the price premiums and discounts associated with alfalfa hay quality grades. Previous research has mainly focused on how attributes of alfalfa hay influence the price received. In this study, we use ordinary least squares linear regression and visual data representations to examine the effects of market strength on price received in conjunction with hay quality. The results demonstrate that during periods of relatively high average prices of alfalfa hay there is no significant impact on the average premiums and discounts associated with hay quality. However, during periods of relatively low average prices, there are notable changes in the premiums and discounts for alfalfa hay quality grades. These findings can help alfalfa hay producers make better decisions by understanding how market strength affects the prices they receive, which can influence their production practices.

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Introduction

Alfalfa hay is a major crop produced in the United States, ranking fourth in total production across all crop varieties (NAAIC, 2017). In 2022, the United States produced nearly 48.4 million tons of alfalfa on approximately 16.8 million acres (USDA NASS, 2024c; USDA NASS, 2024a). The United States Department of Agricultural estimated the value of national alfalfa hay production to be $10.57 billion in 2023 (USDA NASS, 2024d). These statistics underscore the sheer size of the alfalfa hay industry in the United States. The economic value an alfalfa hay producer receives for their output is often considered as a function of its quality attributes (Rudstrom, 2004; Peake et al., 2019; Hopper et al., 2004). These quality attributes are non-homogenous, setting the alfalfa hay market apart from staple commodity crops such as corn and wheat. Recognizing the heterogenous nature of the quality of alfalfa, the United States Department of Agriculture (USDA) established standards to facilitate a consistent grading of alfalfa hay according to various quality attributes. Through adhering to these grading standards, market participants can more easily assess and compare the quality of alfalfa hay, aiding in the price discovery process. The USDA grading system categories hay into one of five quality grades: utility, fair, good, premium, and supreme. To qualify for a quality grade label, the hay must meet specific benchmarks within several measurable hay quality metrics as outlined in Table 1 (USDA LPGMN, n.d.). Acid detergent fiber (ADF) is one measure of the digestibility of a hay sample and is an essential component in the calculation of total digestible nutrients (TDN). Neutral detergent fiber (NDF) is an estimate of cellulose, hemicellulose, and lignin content in a sample. NDF is negatively correlated with forage intake meaning that high quality hay samples will have low NDF levels. Crude Protein (CP) is a measure of the total amount of protein, or nitrogen content, in a sample of hay. Relative feed value (RFV) is a metric measuring the joint digestibility and intake potential of hay. The quality of hay improves as its relative feed value increases. RFV is one of the biggest determinants of the quality classification that hay receives (USDA NCRS, 2000).

Table 1. Alfalfa Quality Guidelines

Quality Grade	ADF	NDF	RFV	CP	TDN-100%
Supreme	<27	<34	>185	>22	>62
Premium	27-29	34-36	170-185	20-22	60.5-62
Good	29-32	36-40	150-170	18-20	58-60
Fair	32-35	40-44	130-150	16-18	56-58
Utility	>35	>44	<130	<16	<56

Notes: Sourced from USDA, AMS. Guidelines for alfalfa hay for domestic livestock use. Hay not to include more than 10% grass

These five quality grades, as outlined by the USDA, have a large impact on the price discovery process. Past research has routinely demonstrated a strong positive relationship of quality grade with prices. Hay with relatively higher quality grades routinely garner premiums relative to hay with comparatively lower grades. Rudstrom (2004) found that hay with a higher RFV received a higher price compared to hay with a lower RFV at a hay auction in Minnesota. Hopper, et al. (2004) similarly found that any alfalfa hay sold at a given Wisconsin auction possessing a quality grade lower than prime (prime being the highest quality standard used in their study) resulted in a discounted price. The discounts received were found to increase as hay quality decreased below prime. Though the impact of quality grades on price is established in the literature, little is known about how this impact may change through time, especially considering the relative strength of the hay market at any given time. Can the premiums by quality grade be assumed constant during periods of strong (weak) hay market prices? The primary objective of this study is to determine if the magnitude of premiums and discounts received for differing quality grades of alfalfa hay are influenced by the average market price for alfalfa hay. When average market prices are high, does this affect the premiums received for hay of relatively high quality grades in the same way it affects the discounts received for hay of relatively low quality grades? Likewise, when average market prices are low, are the effects on premiums and discounts the same? This study intends to provide answers to these questions.

Understanding the effect of average market price on the premiums and discounts received has direct implications for alfalfa hay producers. As demonstrated by Donker & Marten (1972), harvesting at different stages of maturity effects both quality and yield of alfalfa hay. An early harvest will result in higher average quality but lower average yields in comparison to a later harvest. By understanding the marginal effect that average market price has on premiums and discounts received for quality grades, an alfalfa hay producer can make more informed decisions to maximize profitability. For example, this understanding would allow a producer to weigh the benefits of higher quality hay compared with the cost of expected yield losses when considering their harvest time decision. In other words, this understanding may lead producers to change focus from quality to yield or vice versa dependent on the average market price in an effort to maximize profit.

Literature Review

The observable differences in alfalfa hay from one quality grade to the next have definitive implications on animal performance. A study conducted at the University of

Minnesota (Donker & Marten, 1972) found that heifers fed higher quality alfalfa hay performed better in multiple regards. The study fed two different maturities of alfalfa hay to two groups of heifers. The first maturity of hay – early hay – was harvested at the early-bloom stage. The second maturity, – late hay – was harvested at full-bloom stage. The early hay possessed greater crude protein, lower NDF, lower ADF, and higher TDN values compared to the late hay implying that the early hay was of higher quality than the late hay. Their results found that the heifers that were fed early hay weighed 7.6 percent more than the heifers that were fed late hay at the end of the year. Additionally, though not statistically significant, over the total lactation period of the study, heifers fed early hay produced 0.8 pounds more milk per day than those fed late hay. Findings presented by Lacefield (1988) concluded similarly— higher quality alfalfa hay fed in a dairy setting resulted in higher milk production in comparison to lower quality alfalfa hay. Lacefield (1988) also presented data concluding that higher quality alfalfa hay resulted in a higher average daily gain in beef steers.

Because of the observable positive correlation between higher quality alfalfa hay and animal performance, consumers recognize that there is increased production value in higher quality alfalfa hay. This increased production value results in increased willingness to pay for hay of relatively higher quality grades.

Hopper, et al. (2004) found in a study on the effects of quality on alfalfa price received that there are non-linear discounts received for alfalfa hay with decreasing RFV. They concluded that "according to the pricing system that relies on RFV standards, it is advisable for producers to produce alfalfa with at least RFV of 125 (Standard 1) to avoid increasingly larger discounts (Hopper, et al., 2004, p. 681)." One study performed by the

University of Kentucky analyzing grass hay also found that, regardless of bale type, auction prices for hay with higher TDN values were increased relative to hay with lower TDN values (Dant et al., 2017). A study done by the University of California in conjunction with UC Cooperative Extension, University of Nevada Cooperative Extension, and Nevada Farm Bureau (Mayland et al., 1998) focused on the effects of feeding two different qualities of an alfalfa/tall fescue mix on animal performance. They concluded that the higher quality hay resulted in an increased production that they estimated to be valued at $15/ton of forage fed.

McCullock et al. (2014) used a hedonic regression model and found that - at the 0.01 significance level - there were increasing, positive marginal effects on price for each alfalfa quality grade above fair and a negative marginal effect on price for alfalfa graded below fair. Rudstrom (2004) also used a hedonic model approach and had findings that aligned with the findings of McCullock et al. (2014). Rather than using quality grades as variables in the hedonic model (where hay price was the dependent variable), they used a continuous variable representing RFV. The corresponding parameter estimate had a positive value and was statistically significant at the 5% level. While this study did not explicitly specify what type of hay the analysis was performed on, this again demonstrates the idea that quality has a positive effect on the price received for hay. Peake et al. (2019) created seven hedonic models examining the effect that different attributes such as hay type, bale weight, bale type, lot size, and quality measures had on hay price received at an auction. It was consistently concluded through their models that the quality measures examined (TDN and RFV) had statistically significant parameter estimates. The coefficients all had positive values demonstrating that as quality increases, the price received also increases.

Extensive research has concluded that hay quality, both within alfalfa hay as well as other varieties of hay, affects the price received for hay. Hay that is of higher quality receives a higher price on average while hay that is of lower quality receives a discounted price.

While research has been done to examine the effect of quality on price, little has been done to examine this relationship through time. Likewise, little research has been done to examine the impact of the overall strength of the alfalfa hay market on the premiums and discounts received for high and low quality hay. Understanding the value that the alfalfa hay market puts on quality during times of differing market conditions would add valuable insight for both producers and consumers. This study looks to examine the effects, if any, that the strength of the alfalfa hay market has on the price premiums and discounts received for quality.

Data and Methods

Though alfalfa hay is a common commodity, obtaining sales and price data is challenging. There are no futures markets for alfalfa hay and only limited price reporting. Additionally, it is common for alfalfa hay to be grown and fed to livestock within the same operation. When this occurs, no market transaction takes place for this hay, resulting in an incomplete price discovery process. Thus, the monetary value for this hay is not established which further impacts the volume of hay pricing data available. USDA AMS publishes weekly direct hay reports for sixteen states/regions that include sale price information and hay quality grades (USDA AMS, 2024). Data for this study was compiled from these weekly direct hay reports across all sixteen states/regions from January 2000 to January 2024.

The dataset that was compiled has a structure that aligns with repeated cross-sectional data. While the dataset spans a significant timeframe (January 2004 to January 2024) with weekly observations, each time point captures transactions reported from an unidentified set of individuals. Many of these individuals reporting prices may consistently report prices through time. However, within any given week new individuals may report prices or previous individuals may have nothing to report and would not be included. As no individual identifying information is included in the reports, each observation must be treated as independent. This focus on independent samples at each time period, rather than following the same units over time, characterizes repeated cross-sectional data. In repeated cross-sectional data, the focus is on capturing snapshots of the population at multiple points in time, allowing for the analysis of changes and trends within the population, despite the samples being independent across time periods.

While the hay transaction reports furnished by USDA AMS contain information on multiple varieties of hay, the observations in the dataset created for this analysis were constrained to only include alfalfa hay. The Alabama Direct Hay Report did not include any observations for alfalfa hay. Therefore, no observations were used from the Alabama report, reducing the number of states/regions included in the dataset to fifteen. Each observation in the dataset recorded transactional information including the sale price, sale report date, quality grade, bale type, and a variable indicating if the sale price included the delivery to the buyer. Observations in the dataset were further constrained to only include transactions for which the sale price was reported in a dollar per ton basis. This constraint removed observations for which sales were reported on a dollar per bale basis. These per bale transactions could be retained by converting to a per ton basis using assumed bale weights. However, the assumptions around bale weights would add uncertainty and variability to these converted transactions. Additionally, the overall size and balance across bale types for this dataset was not critically impacted by removal of the per bale transactions. Thus, for these reasons, as well as to maintain consistency across reported sales, we chose to remove the per bale transactions from the final data set. The reported sale prices were deflated using a general consumer price index published by the Bureau of Labor Statistics (BLS) (BLS, 2024) with 2023 used as the base or reference year for all real prices. Summary statistics for the alfalfa hay sales in the USDA, AMS direct hay reports used in this study are outlined in Table 2.

The dataset consisted of 26,696 observations. Each transaction was designated to one of the five USDA quality grades: utility, fair, good, premium, or supreme. For this study the utility and fair grades were combined into a single utility/fair category. Only 1.45% and 16.49% of total observations were of utility and fair grades respectively. The limited reporting among these grades necessitated this change to help provide greater balance across the observed quality grades. Additionally, the mean real prices for all observations of utility and fair quality hay were $212.72/ton and $225.30/ton respectively. These relatively similar mean prices provided further motivation for the combining of these two quality grades. The observations included in the dataset were constrained to the following bale types: large round, 4x4 square, 3x4 square, 3x3 square,

Table 2. Alfalfa Hay Summary Statistics by Quality Grades From USDA, AMS Direct Hay Reports January 2000 to January 2024

	Quality Grade				
Price Received[a]	**Utility/Fair**	**Good**	**Premium**	**Supreme**	**All Qualities**
Mean	$222.02	$248.72	$300.39	$314.89	$275.33
Standard Deviation	60.92	63.24	69.92	68.35	75.04
Median	$209.21	$237.13	$296.99	$307.89	$266.89
Minimum	$59.81	$89.84	$76.99	$144.03	$59.81
Maximum	$458.67	$515.28	$592.62	$592.62	$592.62
Bale Type	**Utility/Fair**	**Good**	**Premium**	**Supreme**	**% of Total**
Large Round	1468	765	187	78	9.36%
4x4 Square	1311	2715	3466	2634	37.93%
3x4 Square	1819	1887	1588	736	22.59%
3x3 Square	44	167	517	222	3.56%
2 Tie Small Square	83	1555	3040	1782	24.20%
3 Tie Small Square	65	131	416	20	2.37%
Total	4790	7220	9214	5472	26696
Report[b]	**Utility/Fair**	**Good**	**Premium**	**Supreme**	**% of Total**
California	219	289	400	172	4.05%
Colorado	49	120	172	43	1.44%
Idaho	208	61	53	30	1.32%
Iowa	0	31	34	11	0.28%
Kansas	2313	1162	519	554	17.04%
Missouri	122	122	122	122	1.83%
Montana	102	134	44	9	1.08%
Nebraska	77	429	91	39	2.38%
New Mexico	129	130	960	0	4.57%
Oklahoma	12	98	107	68	1.07%
Oregon	49	183	319	54	2.27%
South Dakota	104	84	89	90	1.37%
Texas	1120	4094	6014	4253	57.99%
Columbia Basin	206	76	79	13	1.40%
Wyoming	80	207	211	14	1.92%
	Utility/Fair	**Good**	**Premium**	**Supreme**	**% of Total**
Delivered[c]	44.20%	49.75%	47.05%	59.48%	49.81%

[a] Prices are real prices ($/ton) with a 2023 reference year.
[b] As designated by the USDA AMS direct hay reports.
[c] Percent of observations that included delivery to the purchaser in the sale price.

2 tie small square, and 3 tie small square. Within the AMS reports some transactions were listed as “large square” bales. These transactions were combined with the “4x4 square” transactions as 4x4 bales are often referred to as large square bales within the hay industry and were assumed to be synonyms within the hay report data.

The dataset is well balanced across bale types and quality grades while across states/regions the data is limited by a notable imbalance. Specifically, 57.99% and 17.04% of all observations are from the Texas and Kansas direct hay reports respectively. No other state or region included in the dataset accounted for more than 5% of total observations. While this constrains the generalizability of our findings geographically, overall, the variation in the dataset provides a strong foundation to begin to address the objectives of this study.

Methodology

With a goal to understand the effect of the market’s strength on premiums and discounts received for various quality grades, it is necessary to be able to quantify the condition of the market at a given point in time. To do this, the monthly national average alfalfa hay price was first retrieved from USDA NASS (USDA NASS, 2024b). The retrieved prices covered the same period as the dataset that was constructed for this study (i.e., Jan. 2000 – Jan. 2024). The consumer price index was used to deflate the monthly national average alfalfa hay prices to real dollars with a reference year of 2023 (BLS, 2024). Months with prices in the bottom 25th percentile of all monthly average prices were labeled with a dummy variable, *Low-Price Era*, equal to 1 if the average monthly price was in the bottom 25^{th} percentile and equal to 0 otherwise. Similarly, months with average prices in the top 25th percentile were designated with the dummy variable, *High-*

Price Era. Months falling between the 25th and 75th percentiles were considered to reside in a “normal price era”. After categorizing monthly observations within the USDA NASS national average price data set into their respective market-strength-eras, all observations in the alfalfa direct hay report data set were similarly categorized into their respective eras. This was accomplished by aligning each observation with the appropriate era dummy variable based on the month and year in which the hay transaction took place. As an example, the average real alfalfa price as reported by USDA NASS in January 2000 was among the bottom 25th percentile of all months' average real prices. Consequently, all hay transactions from January 2000 were coded as belonging to the low-price era. Designating the hay transactions as belonging to low-price and high-price eras serves as means for the quantification of the alfalfa hay market strength through time.

An ordinary least squares (OLS) regression model was developed to evaluate the effect of the two price-eras on the real price received for alfalfa as in

1) $$Real\_Hay\_Price_i = \beta_{1i} + \beta_2 Year_i + \beta_3 Delivered_i + \beta_4 Utility/Fair_i + \beta_5 Premium_i + \beta_6 Supreme_i + \beta_7 Large\_Round_i + \beta_8 2\_Tie\_Small\_Square_i + \beta_9 3\_Tie\_Small\_Square_i + \beta_{10} 3x3\_Square_i + \beta_{11} 3x4\_Square_i + \beta_{12} HP\_Era_i + \beta_{13} LP\_Era_i + \beta_{14} HP\_EraXUtility/Fair_i + \beta_{15} HP\_EraXPremium_i + \beta_{16} HP\_EraXSupreme_i + \beta_{17} LP\_EraXUtility/Fair_i + \beta_{18} LP\_EraXPremium_i + \beta_{19} LP\_EraXSupreme_i + \varepsilon_i$$

where $Real\_Hay\_Price_i$ is the real sales price of alfalfa hay (2023 dollars) for the *i*th observation received by the seller, $Year_i$ is a continuous time trend variable designating the year in which the hay transaction occurred, $Delivered_i$ is a binomial variable indicating if delivery to the buyer was included in the real sales price, $Utility/Fair_i$, $Premium_i$, and $Supreme_i$ are binomial variables indicating the quality grade of an observation, $Large\_Round_i$, $2\_Tie\_Small\_Square_i$, $3\_Tie\_Small\_Square_i$, $3x3\_Square_i$, and$3x4_Square_i$ are binomial variables indicating the bale type of an observation, HP_Era_i and LP_Era_i are binomial variables which indicate if an observation is in either a high-priced or low-priced era respectively, and ε_i is the random error term. Table 3 provides definitions for all variables used in the analysis.

It was hypothesized that the parameter estimate for *Delivered* would have a positive sign. This can be deduced as it is reasonable assumption that there is added value in the product being delivered which would be reflected in the price received. All quality grades were included in the model with the exception of *Good*. The remaining three quality grades (*Utility/Fair*, *Premium*, and *Supreme*) have parameter estimates that show the relationship between each grade relative to *Good* quality. Thus, it was hypothesized that *Utility/Fair* would have a negative sign on the parameter estimate while *Premium* and *Supreme* would have positive signs on their respective parameter estimates (Hopper, et al. 2004.; Peake et al., 2019; McCullock et al., 2014). The bale type 4x4 Square was dropped from the model resulting in the parameters for all other bale types being estimated relative to *4x4_Square*. Based on the work of Peake et al. (2019) and McCullock et al. (2014), it was hypothesized that *Large_Round* would have a negative sign on its parameter estimate and both *2_Tie_Small_Square* and *3_Tie_Small_Square* would have a positive sign on their respective parameter estimates. Peake et al. (2019) concluded that bale weight had a negative effect on price/ton. For this reason, it was hypothesized that the parameter estimates for *3x4_Square* and *3x3_Square* would have positive signs indicating a positive impact on price/ton compared to the relatively heavier *4x4_Square* bales.

It was hypothesized that the variables representing the low-price era and high-price era would have negative and positive parameter estimates respectively. Intuitively one would expect a negative marginal effect to be estimated for *LP_Era* suggesting the price of alfalfa hay would be lower on average during eras of low prices with the opposite intuition holding true for *HP_Era*. Interaction terms for the respective price eras and quality grades were included with equation (1). Due to limited knowledge from prior research, no attempt was made at hypothesizing signs for the parameters of these interaction variables. Evaluating the signs, magnitudes, and statistical significance of these parameter estimates is central to the objectives of this study. Plausible arguments could be made for both negative and positive signs for these variables. For example, it could be hypothesized that the *LP_Era X Supreme* parameter might be negative. If high supply drives the lower relative prices, and demand for supreme quality hay is relatively less elastic than for good quality graded hay, this would result in a decreased price for supreme quality hay relative to good quality hay in a low-price era. Conversely, if the demand for supreme quality hay in a low-price era is more elastic than good quality graded hay, than a positive parameter estimate would be expected. Additional supply and demand relationships together with strategic production decisions in times of relatively low/high prices may result in positive or negative estimated effects for these interaction terms. This study seeks to provide evidence for the direction and magnitude of movement in the premiums and discounts associated with quality grades during periods of relatively low/high eras of prices.

Table 3. Variable Definitions

Variable	Variable Type	Description
Real_Hay_Price	Continuous	Adjusted price using BLS CPI (2023 base year)
Year	Continuous	Number of years post 1999
Delivered	Binomial	1 if delivered, 0 if otherwise
Utility/Fair	Binomial	1 if grade is utility or fair, 0 if otherwise
Good	Binomial	1 if grade is good, 0 if otherwise
Premium	Binomial	1 if grade is premium, 0 if otherwise
Supreme	Binomial	1 if grade is supreme, 0 if otherwise
Large_Round	Binomial	1 if bale type is large round, 0 if otherwise
4x4_Square	Binomial	1 if bale type is 4x4 square, 0 if otherwise
3x4_Square	Binomial	1 if bale type is 3x4 square, 0 if otherwise
3x3_Square	Binomial	1 if bale type is 3x3 square, 0 if otherwise
2_Tie_Small_Square	Binomial	1 if bale type is 2 tie small square, 0 if otherwise
3_Tie_Small_Square	Binomial	1 if bale type is 3 tie small square, 0 if otherwise
LP_Era	Binomial	1 if in low-price era, 0 if otherwise
HP_Era	Binomial	1 if in high-price era, 0 if otherwise
LP_Era X Utility/Fair	Binomial	1 if low-price era & grade is utility/fair, 0 if otherwise
LP_Era X Good	Binomial	1 if low-price era & grade is good, 0 if otherwise
LP_Era X Premium	Binomial	1 if low-price era & grade is premium, 0 if otherwise
LP_Era X Supreme	Binomial	1 if low-price era & grade is supreme, 0 if otherwise
HP_Era X Utility/Fair	Binomial	1 if high-price era & grade is utility/fair, 0 if otherwise
HP_Era X Good	Binomial	1 if high-price era & grade is good, 0 if otherwise
HP_Era X Premium	Binomial	1 if high-price era & grade is premium, 0 if otherwise
HP_Era X Supreme	Binomial	1 if high-price era & grade is supreme, 0 if otherwise

Results and Implications

Equation (1) was estimated using ordinary least squares regression and the results are summarized in Table 4[1]. The results indicate that bale type, quality grade, *Year* and *Delivered* all significantly influenced the price received. The adjusted r-squared of 0.5669 indicates over half of the variation in the real price received for the observations

[1] Post estimation of equation 1) the predicted values were plotted against the residuals (Figure A1 in the appendix) to evaluate the model for heteroskedastic errors. No strong heteroskedastic pattern was observed.

in the model is explained by the included independent variables. The intent of this model was not to capture all variables that affect alfalfa hay prices. Rather, the model intends to understand the effect of the relative strength of the alfalfa hay market on prices received. Additional variables could have been included in the model to increase the goodness of fit[2]. However, as long as omitted variables are uncorrelated with quality grades and the low and high-price eras, their omission is expected to not affect the model findings with respect to the objectives. The parameter estimate for *Year* is 1.971, significant at the 1% level. This indicates that the marginal effect of each additional year is an increase of $1.91/ton of alfalfa hay on average. This suggest that even after accounting for inflation prices are increasing year over year on average by $1.91/ton. A plausible explanation for this finding is the increased export demand over the years of this dataset. This increased export demand is a demand shifter increasing total alfalfa hay demand and subsequently increasing prices. *Delivered* has a parameter estimate of 37.830 and is significant at the 1% level. On average, if the transaction included delivery to the buyer, this hay received a premium of $37.83/ton over hay that did not include delivery. This aligned with the hypothesized sign for this variable.

The parameter estimates for each of the three quality grades included in the model are statistically significant at the 1% level. *Utility/Fair* had a parameter estimate of -19.043 indicating that on average, holding all else equal, each ton of *Utility/Fair* grade hay received a price $19.04/ton lower than hay that was of the quality grade good. *Premium* and *Supreme* had parameter estimates of 41.86 and 54.52 respectively

[2] State/region fixed effects were also considered. Due to the imbalance within the dataset across states/regions we chose to omit this state/region variables from the model. The estimated results with these state/region fixed effects included are summarized within Table A1 of the appendix.

indicating the average premiums in dollars per ton received for these respective quality grades relative to *Good.* These findings are consistent with both the hypothesized signs for these variables and the existing literature (Dant et al., 2017; Hopper, et al. 2004; Mayland et al., 1998; Peake et al., 2019; McCullock et al., 2014).

Table 4. Alfalfa Hay Price Estimated Regression Output Evaluating the Effect of Relative Market Strength

N:	26696	F-Value:	1942
Adjusted R-squared:	0.5669	DF:	26677
Variable	**Parameter**	**Estimate**	**Std. Error**
Constant	178.836	***	1.450
Year	1.971	***	0.071
Delivered	37.830	***	0.685
Utility/Fair	-19.043	***	1.619
Premium	41.855	***	1.269
Supreme	54.522	***	1.434
Large_Round	-58.980	***	1.370
2_Tie_Small_Square	61.014	***	0.808
3_Tie_Small_Square	35.824	***	2.177
3x3_Square	-25.334	***	1.841
3x4_Square	-17.609	***	1.090
HP_Era	53.318	***	1.336
LP_Era	-29.035	***	1.702
HP_Era X Utility/Fair	-1.636		2.041
HP_Era X Premium	0.790		1.732
HP_Era X Supreme	-2.086		1.980
LP_Era X Utility/Fair	-15.665	***	3.404
LP_Era X Premium	-10.107	***	2.193
LP_Era X Supreme	-5.209	**	2.477

Notes: *, **, *** indicates significance at the 10%, 5%, and 1% levels, respectively.

The parameter estimates for each bale type included in the model are statistically significant at the 1% level. The 4x4 square bale type was omitted from equation one and serves as the refence bale type when interpreting the parameter estimates for the other bale types within the model. Large round bales, 3x3 square bales, and 3x4 square bales are estimated as having average discounts relative to 4x4 square bales of $58.98, $25.33, and $17.61/ton respectively. Whereas 2 tie small square bales and 3 tie small square bales are expected to receive average premiums of $61.01 and $35.82/ton respectively relative to 4x4 square bales. These results align with the hypothesized sign for each variable with the exception of *3x4_Square* and *3x3_Square*. Contrary to the findings of Peake et al. (2019), even though these bales are lighter than a 4x4 square bale, they were discounted relative to the large 4x4 square bale. Though these bales are lighter, it is hypothesized that they receive a discounted price due to the limited popularity of these bale types. As outlined in Table 2, there are over 10.5 and 1.6 times more observations for 4x4 square than 3x3 and 3x4 square bales respectively. With 4x4 square bales being the most common bale size, it could be hypothesized that other large bale sizes receive a discount because many operations may be set up to use 4x4 square bales. Therefore, it is possible that these bales receive less value due to the inefficiencies experienced by incorporating these smaller bale sizes.

Parameter estimates for both *Low-Price_Era* and *High-Price Era* were statistically significant at the 1% level. The results suggest that prices in low-price eras and high-price eras are expected to be $29.04/ton less and $53.32/ton more respectively on average than prices in normal priced eras. The era variables were constructed as percentiles (top and bottom 25th percentile) of the national average real alfalfa prices reported by USDA, NASS. The national average alfalfa prices are expected to correlate highly with the direct hay report prices in the corresponding time periods. Thus, the findings of direction and significance of the marginal effects of the era variables is expected (nearly predetermined).

The parameter estimates for the interaction between each of the three quality variables and era variables are of much more importance to the accomplishment of this study's objectives. The coefficients for the quality interactions with the low-price era were each estimated with a negative sign and are statistically significant at a maximum of the 5% level. The results suggest that utility/fair quality hay in a low-price era receives an additional price reduction on average of $15.67/ton relative to good quality hay in the same era. This discount would be applied together with the average discount of $19.04 for utility/fair hay regardless of pricing era. Premium and supreme quality hay in a low-price era receive a price reduction of $10.11 and $5.21/ton respectively in comparison to good quality hay in a low-price era. This suggests that the price spread of premium and supreme quality hay shrinks during low-price eras whereas the spread of utility/fair hay expands (larger disparity in favor of good quality hay).

The parameter estimates for the interactions between the high-price era and the three included quality grades within the model vary in estimated sign but none are found to be significant at the 5% level. Additionally, the magnitudes of these high-price era x quality grade interactions are much smaller compared to their low-price era counterparts. The results imply that there is not enough evidence to suggest periods of relatively high alfalfa prices have a consistent and significant effect on the marginal effects of quality grade premiums and discounts relative to good quality hay.

Table 5 demonstrates the expected price of alfalfa hay by quality grade and price era while holding all else constant within equation (1). Additionally, the expected price spread between each quality grade relative to “good” quality is also displayed within Table 5. When comparing the spread for each quality in the *Low-Price_Era* with the spread in the normal price era, it becomes clear that the spreads for premium and supreme quality hay are reduced, whereas the spread for utility/fair quality hay widens. When comparing the spread for each quality in the *High-Price_Era* with the spread for normal price era the differences noted are minimal and would have little practical implication even if they had been found to be statistically significant.

Table 5. Effect of Price Eras on Average Alfalfa Hay Price[a] Received by Quality Grade

	Low-Price Era		**Normal Era[b]**		**High-Price Era**	
Quality Grade	**Est. Price**	**Spread[c]**	**Est. Price**	**Spread**	**Est. Price**	**Spread**
Utility/Fair	$171.17	(-$34.71)	$215.87	(-$19.04)	$267.55	(-$20.68)
Good	$205.88	($0.00)	$234.91	($0.00)	$288.23	($0.00)
Premium	$237.63	($31.75)	$276.77	($41.85)	$330.88	($42.65)
Supreme	$255.19	($49.31)	$289.43	($54.52)	$340.67	($52.44)

[a]*Average prices were calculated by holding all variables from the estimated equation (1) at their means with the exception of eras and quality grade.*
[b]*Normal Era is composed of all observations that do not fall into the Low-Price Era or High-Price Era*
[c]*Spread is a calculation of the difference between a given quality grade and quality grade “good.”*

After empirical analysis through estimation of equation (1), a graphical analysis is completed for comparison. Figure 1 graphs the observed conditional average price spread by quality grade (relative to good) and era within the dataset. A trendline was added for each quality grade spanning all three categories. Comparing the graphical results to those outlined in Table 5 adds robustness to the empirical findings. In the low-price era, average price spreads for premium and supreme quality hay are reduced while the average price spread for utility/fair quality expands (more negative) in comparison to the normal price era. In the good price era, there is little variation in the price spreads for each quality grade when compared relative to the normal price era. The linear trendlines in Figure 1 illustrate the idea that as transaction prices increase, the premiums received for premium and supreme quality hay increase while the discounts received for utility/fair quality hay are reduced.

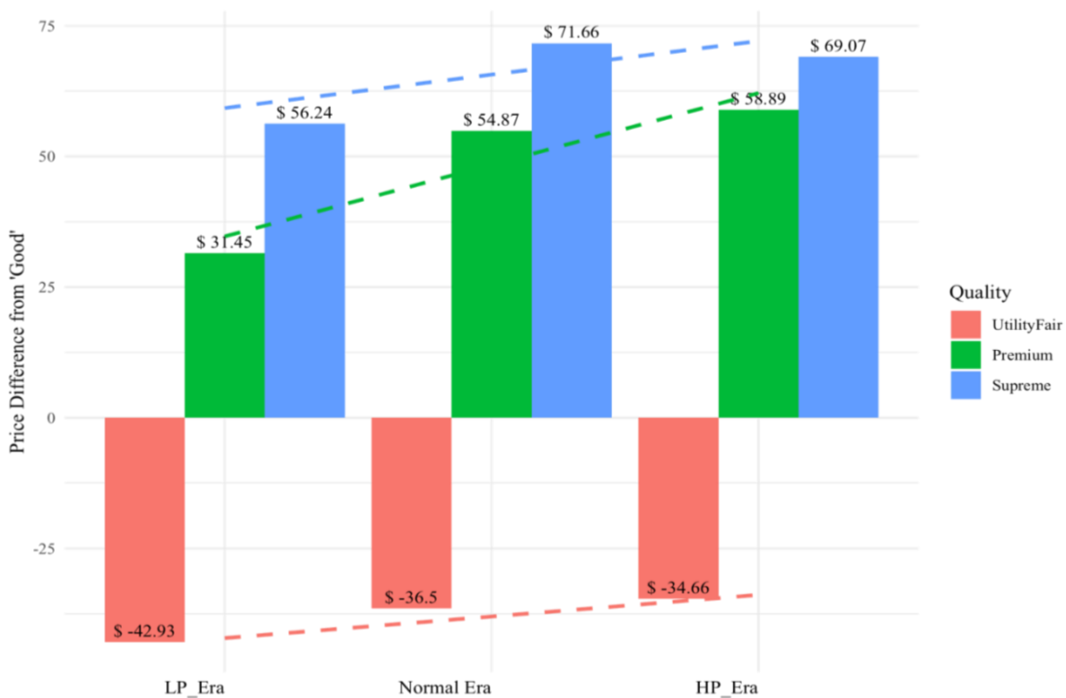

Figure 1: Conditional Average Difference from Quality Grade "Good" By Era
Notes: Normal Era represents observations that were in neither the LP_Era nor the HP_Era

Figure 2 similarly compliments the empirical findings by graphing the price spreads relative to "good" quality through time. The same *LP_Era* and *HP_Era* variables used in the regression model are overlaid on this graph to highlight the eras within the time series. If a given month had a value of 1 on *LP_Era*, it was shaded red. Likewise, if a given month had a value of 1 on *HP_Era*, it was shaded in green. While the trends are not immediately clear, there are periods in Figure 2 where the findings from the regression model can be seen. For example, around 2009-2010, average prices were low as indicated by the red shading reflecting a low-price era. During this period, a trend emerged showing that utility/fair quality hay was receiving a greater discount in comparison to good quality hay. Two examples from the 2012-2014 and 2022-2023 periods illustrate similar findings to the regression model. During these high-price periods, indicated by green shading, the average prices were elevated. Although there is variability in the premium received for supreme quality hay compared to good quality, on

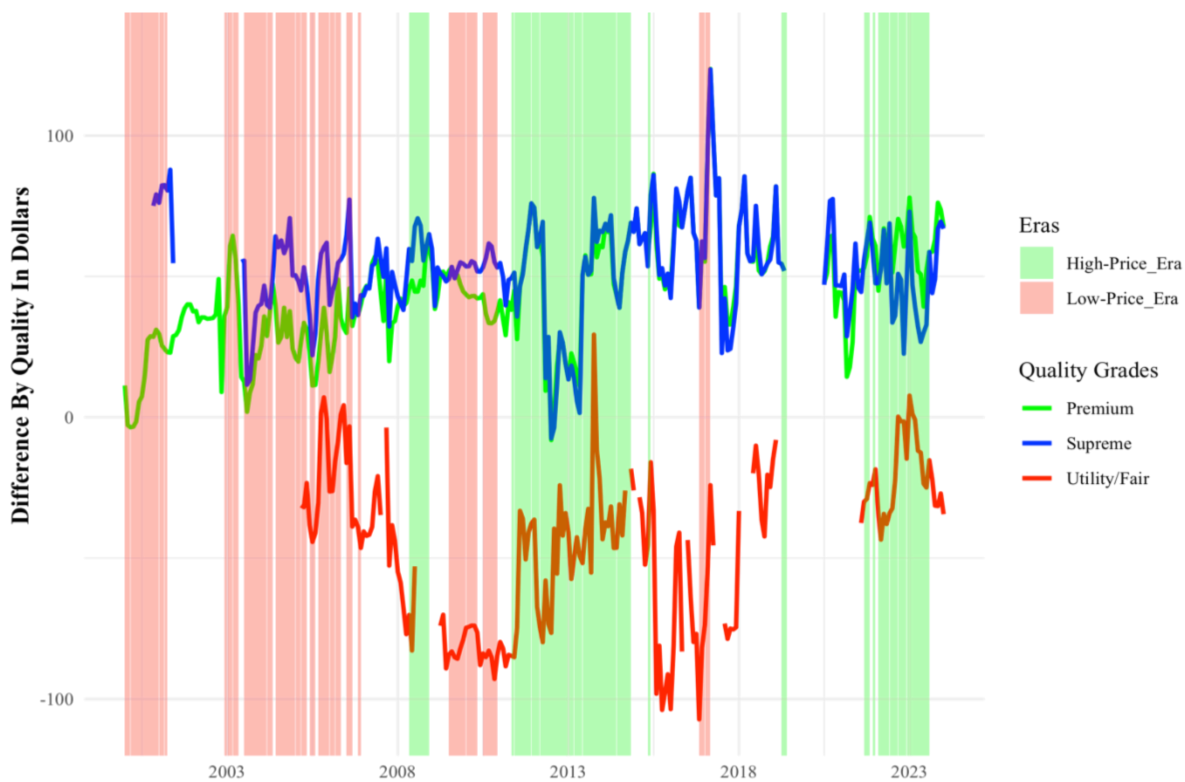

Figure 2: Average Price Difference from Good by Quality
Notes: The difference from the average price for good quality hay and the average price for each other quality of hay. High-Price_Era is all months that had an average price in the top 25% of all months. Low-Price_Era is all months that had an average price in the bottom 25% of all months.

Implications

average, the premiums received during these high-price periods do not appear to differ significantly from those received outside high-price and low-price eras.

Understanding the effect of the relative strength of the alfalfa hay market on premiums and discounts received for varying qualities of hay could affect the decision making for both producers and consumers. For a profit maximizing production firm in a period of low prices, it might not make economic sense to pursue producing higher quality hay. As the premiums for premium and supreme quality hay shrink relative to good, the economic advantage of producing higher quality hay might be offset or even overcome by the increased yield of lower quality hay. With many variables affecting individual alfalfa hay producing operations, the generalized statement that in times of low price, pursuing yield over quality maximizes profit is not always true, but for some operations this may be the case. The decision to pursue yield over quality must be made at the operation level. In periods of low average prices, if the added benefit of an increased yield outweighs the now reduced benefit of higher quality hay, it may be in the best interest of the operation to forgo quality and pursue yield. Understanding the effect of average market prices on premiums and discounts for quality aids producers in making this decision.

Producers may often target higher quality production, yet adverse production conditions or weather events may lead to undesirable reductions in quality. Our results suggest that particularly in periods of low average prices producers should make every effort to avoid utility/fair quality production as prices for these low-quality grades are decreased disproportionately relative to good quality hay.

Because this study found no statistically significant evidence suggesting that high average market prices affect individual quality grade premiums/discounts, producers should not become enamored with the comparatively higher average prices for premium and supreme quality grade hay as compared to good during periods of relatively high prices. Good quality hay increases in value the same amount as utility/fair, premium, and supreme quality hay during times of high prices. There is no evidence found in this study suggesting that producers need to consider changes in production practices solely because average market prices are high.

Understanding the effects of low average prices could aid consumers in reducing their input costs. While alfalfa hay does not have an indefinite storage life, it is common for consuming firms to have supply stocks of alfalfa hay. While all alfalfa hay prices, regardless of quality grade, are lower when the average price is low, the price for utility/fair is the most heavily discounted quality in comparison to good quality hay. If a consuming firm can purchase and then store utility/fair alfalfa hay for later use, they can reduce their input costs by capitalizing on the heavily discounted price for utility/fair quality hay during these periods. On the contrary, the premiums received for supreme quality hay are not as significantly impacted by low average prices. While consumers can still expect comparatively lower premiums required for these higher quality grades relative to good quality during periods of low average price, the discounts expected for utility/fair hay would be of a comparatively larger magnitude. It is likely that operations that can feed utility/fair quality hay already do so. If an operation typically purchases utility/fair quality hay and it is anticipated that average prices will rise, there is no better time to purchase utility/fair quality hay with the intent to create a supply stock than in a low-price era.

Because the premiums and discounts received for varying qualities of alfalfa hay during periods of high average price are not significantly different than during times of average alfalfa hay prices, there is not a specific quality grade that is comparatively a better purchasing option during periods of relatively high prices. During periods of high average prices, all quality grades are affected similarly resulting in increased costs that are consistent throughout all quality grades. There is not a particular quality grade that stands out as a better deal compared to others and consumers should not expect to find one grade more advantageous than another solely based on market strength.

Conclusions and Discussion

This study revealed that various factors, such as quality and bale type, significantly influence the reported sales prices of alfalfa hay. Holding all other factors constant, utility/fair quality alfalfa hay received an average price of $19.04/ton less than good quality hay. In contrast, premium and supreme quality hay garnered prices of $41.86/ton and $54.52/ton more than good quality hay, respectively. Additionally, 2-tie small square and 3-tie small square bales garnered premiums of $61.01/ton and $35.82/ton, respectively, compared to 4x4 square bales. Conversely, large round, 3x3 square, and 3x4 square bales incurred discounts of $58.98, $25.33, and $17.61/ton, respectively, in comparison to 4x4 square bales.

This study successfully achieved its primary objective by uncovering how the average market price (i.e., current market strength) for alfalfa hay influences the premiums and discounts for different quality grades. Particularly, when average market prices are low, the impact on premiums for higher quality hay and discounts for lower quality hay varies. Transitioning from a normal average market price to a low average market price resulted in an additional decrease of $15.67/ton in the discount for utility/fair quality hay compared to the price for good quality hay. However, the effect of low-price eras is not found to be homogeneous across quality grades. The premium for premium quality hay decreased by $10.10/ton, while the premium for supreme quality hay decreased by only $5.21/ton. When average market prices are high, however, the effect on the prices across quality grades is much more homogeneous. We estimate that all hay qualities experience an approximate increase in value of $53.32/ton with no significant differences across grades.

Although data from fifteen states/regions was included, the results are limited by an imbalance in the observations across states/regions. The majority of observations originate from Texas and Kansas, accounting for 75.03% of all data points. Outcomes might vary if this imbalance could be corrected. Moreover, results may diverge for hay varieties beyond alfalfa hay. Subsequent investigations could concentrate on employing similar methodologies to explore diverse geographical markets and other types of hay.

One additional limitation of this study lies in the methodology used to identify high and low average price eras. The chosen methodology does not capture whether high or low prices are driven by supply, demand, or a combination of both. Gaining insights into the factors influencing market price variation would enhance the study. For example, while it's reasonable to assume that abundant supply could lead to lower average prices, this study does not fully grasp how excess supply affects the premiums and discounts for various quality grades of alfalfa hay. Similarly, high demand might contribute to an upward trend in average alfalfa hay prices. Future research should explore alternative methods for characterizing market strength to better discern the impact of supply and demand dynamics on the premiums and discounts associated with different quality grades of alfalfa hay.

Understanding the relationship between market conditions and premiums/discounts for varying qualities of alfalfa hay is crucial for both producers and consumers. In times of low prices, the decision to prioritize yield over quality may vary among operations, with some benefiting from pursuing higher yields considering reduced premiums for higher quality hay. Conversely, operations specializing in lower quality hay may find it advantageous to improve quality during low-price periods to offset the effect of expected increased discounts for lower quality hay during these periods. However, during high-price periods, all quality grades are similarly affected, resulting in a consistent increased price for producers across the board. Therefore, there's no single quality grade that stands out as a better purchasing option for consumers during such times. Overall, comprehending these dynamics aids producers in optimizing production decisions and assists consumers in managing input costs.

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Appendices

Appendix A. Heteroskedasticity Testing

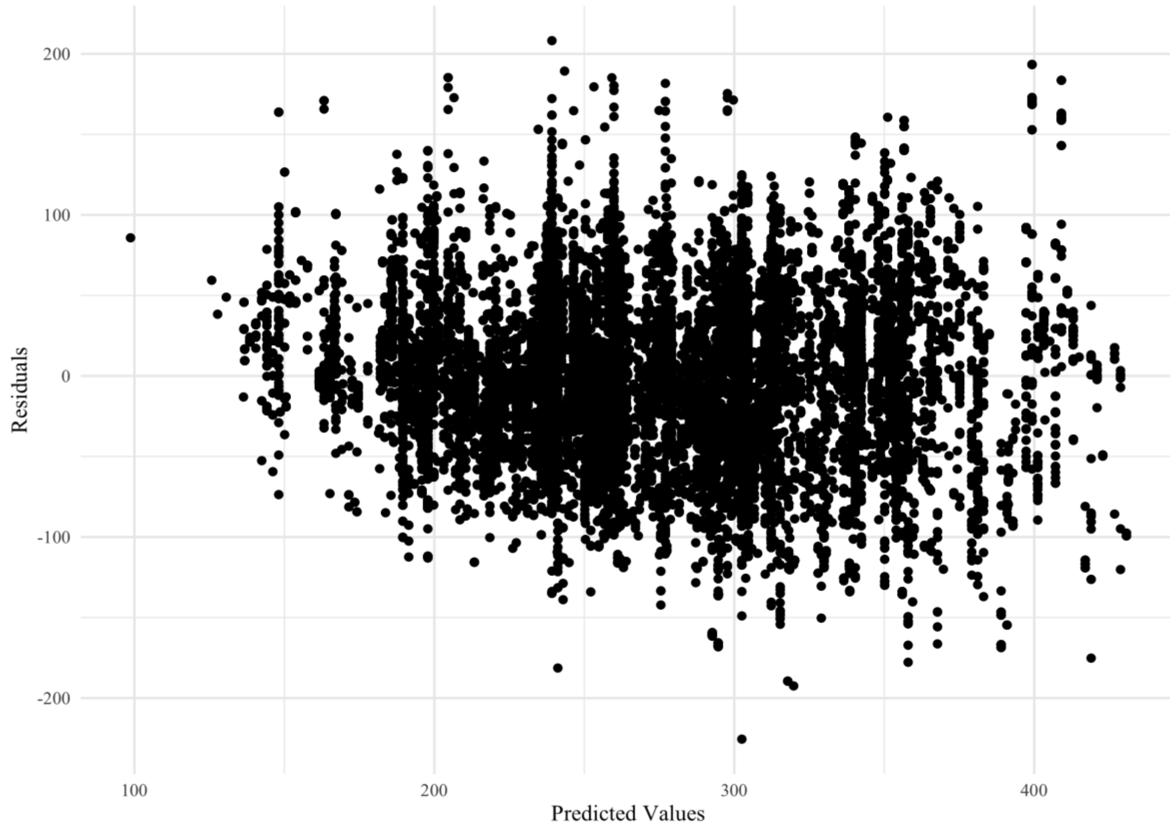

Figure A1: Predicted Prices vs. Residuals for Alfalfa Hay Price Estimated Regression Equation (1)
Notes: The x-axis (Predicted Values) represents the predicted price of each observation in dollars per ton. The y-axis (Residuals) are the residuals of the predicted price compared to the actual price.

Appendix B: State/Regional Effects Model

Table A1 is the output from an OLS regression model where *Real_Hay_Price* was the dependent variable. In this model, Equation (1) was used with the following modifications:

1. A variable for each state/region was created and used in the model. *Missouri* was dropped from the model resulting in the parameter estimates of the other states estimated with respect to *Missouri.*

Similar to the results in Table 4, the quality grade interaction variables with *HP_Era* were not found to be statistically significant. For the *LP_Era* interaction variables, when interacting with *Utility/Fair* and *Premium*, the sign and significance remained similar to the results in Table 4. However, the *LP_Era X Supreme* variable was no longer statistically significant in this model.

Table A1. Alfalfa Hay Price Estimated Regression Output with State/Regional Effects Included

N:	26696		
Adjusted R-squared:	0.6406		
F-Value:	1488		
DF:	26663		

Variable	**Parameter Estimate**		**Std. Error**
Constant	28.874	***	3.001
Year	4.213	***	0.075
Delivered	27.156	***	0.664
Utility/Fair	-17.303	***	1.492
Premium	35.957	***	1.162
Supreme	45.766	***	1.317
Large_Round	-14.299	***	1.453
2_Tie_Small Square	58.535	***	0.740
3_Tie_Small Square	44.888	***	2.236
3x3_Square	24.613	***	1.889
3x4_Square	4.123	***	1.151
HP_Era	59.688	***	1.223
LP_Era	-25.148	***	1.553
HP_Era X Utility/Fair	-3.224		1.866
HP_Era X Premium	0.381		1.592
HP_Era X Supreme	1.594		1.809
LP_Era X Utility/Fair	-21.503	***	3.111
LP_Era X Premium	-4.437	*	2.001
LP_Era X Supreme	0.887		2.260
California	102.324	***	2.760
Colorado	65.718	***	3.198
Idaho	77.901	***	3.368
Iowa	45.802	***	5.634
Kansas	58.952	***	2.308
Montana	85.523	***	3.482
Nebraska	41.816	***	2.833
New_Mexico	79.606	***	2.605
Oklahoma	23.944	***	3.535
Oregon	88.944	***	2.990
South_Dakota	59.161	***	3.241
Texas	138.922	***	2.615
Columbia_Basin	94.668	***	3.320
Wyoming	47.803	***	3.057

Notes: *, **, *** indicates significance at the 10%, 5%, and 1% levels, respectively.

Appendix C: Continuous Era Variable Model

Table A2 is the output from an OLS regression model where an ordinary least squares (OLS) regression model was developed to evaluate the effect of a continuous price era (current market strength) on the real price received for alfalfa as in

2)

$$Real\_Hay\_Price_i = \beta_{1i} + \beta_2 Year_i + \beta_3 Delivered_i + \beta_4 Utility/Fair_i + \beta_5 Premium_i + \beta_6 Supreme_i + \beta_7 Large\_Round_i + \beta_8 2\_Tie\_Small\_Square_i + \beta_9 3\_Tie\_Small\_Square_i + \beta_{10} 3x3\_Square_i + \beta_{11} 3x4\_Square_i + \beta_{12} Era_i + \beta_{13} EraXUtility/Fair_i + \beta_{14} EraXPremium_i + \beta_{15} EraXSupreme_i + \varepsilon_i$$

where Era_i is a continuous variable indicating current market strength and all other variables are as defined in equation (1). The Era_i variable was created as an indexed value of monthly national alfalfa prices compared to the mean national price for this time period.

The parameter estimate for *Era* indicates that for every one percent that the national alfalfa price is above the mean national price, it is expected that the real price received will increase $1.903/ton. Similarly, for every one percent it is below the national mean price, it is expected that the real price received will decrease by $1.903/ton. The limitations of using a continuous variable to measure market strength are twofold: (1) It is not possible to evaluate whether the effect is heterogeneous during weak or strong market conditions using a continuous variable; (2) It is a weak assumption to believe that a relatively small price fluctuation (e.g., ±10%) would affect the premiums and discounts received for different quality grades. Rather, the objective of the study is to determine if there are measurable effects on the premiums and discounts when prices can truly be considered high or low on average. The positive parameter estimates for *EraXUtility/Fair* and *EraXPremium* indicate that when hay is utility/fair or premium quality grade, for every one percent increase in *Era*, price received will increase $0.143/ton and $0.053/ton respectively. The negative parameter estimate for *EraXSupreme* indicates that when hay is supreme quality, for every one percent increase in *Era*, price received will decrease $0.093/ton.

Table A2. Alfalfa Hay Price Estimated Regression Output with Continuous Era Variable

N:	26696		
Adjusted R-squared:	0.6141		
F-Value:	3036		
DF:	26681		
Variable	**Parameter Estimate**		**Std. Error**
Constant	199.468	***	1.176
Year	0.767	***	0.069
Delivered	38.984	***	0.646
Utility/Fair	-23.955	***	1.139
Premium	39.120	***	0.790
Supreme	53.144	***	0.897
Large_Round	-60.212	***	1.291
2_Tie_Small Square	62.050	***	0.764
3_Tie_Small Square	34.401	***	2.053
3x3_Square	-24.693	***	1.733
3x4_Square	-20.033	***	1.023
Era	1.903	***	0.028
Era X Utility/Fair	0.143	***	0.043
Era X Premium	0.053	*	0.032
Era X Supreme	-0.093	**	0.037

Notes: *, **, *** indicates significance at the 10%, 5%, and 1% levels, respectively.