Hedonic Price Analysis of Hay Auction Prices in Kentucky

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Introduction

When buying and selling hay, it is important to understand what factors are influencing the price of hay in that market. However, information on hay markets is not readily available and there has not been much literature written on the topic for several reasons. McCullock et al. (2014) attributes limited information on the hay market to the versatile characteristics of hay auctions or sales. The value of the hay consists of type of hay, size of the bale, quality, transportation costs, value of feed substitutes, and the number and type of buyers and sellers in a given market place according to McCullock et al. The majority of hay produced is fed to livestock and what may be leftover, is sold. However, this is a very small amount that is actually being sold in a market that allows price data to be collected. The hay could also be sold through private treaties which can be contractual and causes little reporting (McCullock et al. 2014).

Another reason as to why there is little information on the hay market is that many farmers view hay as a homogenous commodity instead of recognizing that the quality of the hay will highly impact the value. Therefore, hay quality information is not a major factor when farmers make purchasing decisions. Hay markets are typically localized, creating extreme differences across regions of a given state. Rudstrom (2004) states that local hay markets are due to buyers not traveling far to purchase hay and because the bulkiness of the bales makes hay hard to be transported long distances. The localization of hay markets can also be attributed to transportation costs of hay and local supply and demand conditions.

USDA-AMS reports very few hay auctions and with limited fiscal funding, the number of auctions that are covered are reduced (McCullock et al. 2014). The National Agricultural Statistics Service (NASS) divides state level hay price data into two categories: Alfalfa/Alfalfa Mixes and All Other Hay. This division of hay price data causes little information to be known about the species of hay that falls under 'All Other Hay' which also makes the quality of 'All Other Hay' hard to determine. With limited data and the inability to distinguish hay types in some reporting, it is difficult to make sense of what is truly influencing the price of hay.

These differences in hay markets and limitations in reporting hay auctions or sales, make gathering enough similar data that would be useful in an evaluation of hay markets difficult. The motivation of this research is to provide more information about what is influencing the price of hay and to evaluate the accuracy of the anecdotal evidence. This research will examine data from a Central Kentucky auction and determine how the changes in forage species from year to year influences price.

Ranked 4th in the nation for other hay production and 12th for all hay production[1], hay is an important commodity in Kentucky's agricultural sector. In the USDA's Crop Production 2015 Summary, Kentucky hay producers harvested over two million acres of hay and the yield per acre in tons was 2.4.[2] Hay is a very versatile and commonly used forage for most livestock farms due to a variety of reasons. First, hay can be stored for lengthy periods without losing many nutrients as long as it is protected from weather. Second, there are several different crops that do very well in hay production. Hay can be produced in small or large quantities. Harvest, storage, production and feeding of hay can be done by hand or mechanically. Lastly, because hay can be nutrient-rich, it can be the primary feed for numerous classes of livestock.

Hedonic models are commonly used in finding the value of certain attributes of a particular commodity. Often times, hedonic models are used in feeder cattle analysis such as in Yeboah and Lawrence (2000). In their paper, they model feeder cattle price by a combination of cattle and lot characteristics and market forces. Zimmerman et al. (2012) uses a hedonic model to examine the price of an individual lot of cattle on auction date being dependent on the individual lot characteristics and auction day market forces.

Grisley et al. (1985) examines the interactions between selected characteristics of a Pennsylvania hay auction market, the bidders and hay based on the prices that were paid. The data used was from 107 buyers during the period September 1982-April 1983. This work used a linear multiple regression model

[1] *Kentucky Agriculture Facts*. Second Edition. Kentucky Farm Bureau. Sources: National Agricultural Statistics Service and Census of Agriculture, 2012, total sales including stud fees.

[2] Crop Production 2015 Summary. USDA, National Agricultural Statistics Service. January 2016.

and found that the intended use of hay, perceived quality, and type were significant variables in determining the prices that were paid for hay.

Rudstrom (2004) uses a hedonic model to analyze the significance of quality, bale size and type of hay in influencing the market price of hay. A hedonic model is also used to find out if premiums or discounts are related to the different sizes and types of hay bales. The data used came from a Minnesota auction from 2000 to 2002. Rudstrom found that in comparison to small square bales, large round, square bales and medium round bales were discounted.

McCullock et al. (2014) uses data from the Centennial Hay Auction, in Fort Collins, CO, that consists of alfalfa, grass and alfalfa/grass mixes. McCullock uses a hedonic price model for each hay type, with weighted average prices as the dependent variable and the independent variables included year, month, grade, bale type (size), tonnes per size/grade, and total tonnes offered (whole auction). In this study, McCullock found that large price increases were related to specific grade size combinations, while price reductions were connected with larger sized bales and lower quality grades.

The hypothesis for this research is that better quality hay should result in higher prices according to what type of hay the lot sold is characterized as. McCullock et al. (2014) found that grade differentials were dependent upon the type of forage and those grade differentials were defined as good, premium, supreme and utility. In this paper, the quality of hay will be ranked as high, medium or low quality according to the total digestible nutrient value of each lot sold at auction. If the TDN of the observation of hay ranged from 50 or higher, the hay is considered high quality. If the TDN value ranged from 40-49.99, the hay is considered medium quality and if the hay is 39.99 or below, the hay is sorted as low quality.

Square bales should bring higher prices because they can be transported and sold in larger lot sizes, reducing costs to the seller. Also, square bales offer ease of handling which is more suitable to the equine market. McCullock et al. (2014) states that larger size bales sold at discounts to smaller ones and found that size had an impact on price differentials.

The species of the hay should also have some influence on price due to quality differences across species of hay. Legumes such as alfalfa generally are of higher quality than grasses. Alfalfa hay is also the

most common legume that is produced in Central Kentucky. However, each group of grasses quality levels can vary. According to a publication from the University of Kentucky written by Lacefield et al., "When both grasses and legumes are harvested at the proper stage of plant growth, legumes are usually higher in total digestibility, rate of digestion, protein, and many minerals and vitamins." The publication goes on to say that when properly managed, a mixture of grass and legume will be of higher quality. [3]

Data

The data used in the analysis is time series data collected from a hay auction in Central Kentucky and manually entered by the author. This area is largely a cow-calf area with limited equine and little to no dairy farms. Buyers of the hay are about 70 percent beef producers and 30 percent horse owners according to the County Extension Agent for Agriculture who administers the sale. The annual January sale dates used in the analysis include 2012, 2013, 2014, 2015 and 2016. However, there is some discrepancy in the weights of each lot sold for the year 2014. In that year, the weights for each lot sold were not recorded and therefore, missing from the dataset. To account for the missing weights, each lot was sorted according to the form and the weights were averaged together over 2012, 2013, 2015 and 2016 and were entered in as the 2014 bale weights with their respective bale types. Several observations were excluded from the analysis due to missing information such as bale weight, nutrient values and lot sizes. There were also a few observations thrown out, such as straw hay and rye hay due to no nutrient data being included.

The data contains 206 observations that include approximately 30-40 lots of hay sold for each year. At the auction, hay is examined visually and nutrient test data made available to the buyers. The dataset is from a single auction location and includes the following information for each lot of hay sold: forage species, form (square vs. round), bale weight (pounds), lot size, quality measures (crude protein and TDN), total precipitation, average temperature and live cattle futures. The forage species is sorted

[3] Lacefield et al., "*Quality Hay Production*." AGR-62. University of Kentucky College of Agriculture.

into three different categories based on each observations description: Alfalfa Mix, Mixed Grass and Timothy, Orchard, Clover. It is anticipated that the species of hay and the quality measures will have the most influence on the price of hay. Lot size refers to the number of bales sold for each observation. The lot size of the hay being sold should not have too much influence on the price of hay and neither should bale weight.

The average temperature is used in the data set is based on the recorded temperature for Madison County in Kentucky over April through August. Total precipitation is the total rainfall for Madison County over the April-August time period. Total precipitation and temperature should have some influence on the price of hay as the two variables are important in the production of hay. Live cattle futures are included to capture the demand for hay from cattle producers and was determined using the Livestock Marketing Information Center's monthly live cattle futures report. The futures price used in the data set is the February futures price for the month of January for years 2012-2016. Live cattle futures should also have a positive effect on hay price as cattle producers are the primary buyers at the hay auction.

Three different quality measures are included in the data set: crude protein, total digestible nutrients and relative feed value. Crude protein explains the percent of protein that the hay contains which can range from six percent to eight percent in native grass hays and about 15 percent or higher in high quality legume hays. Relative feed value is an index that determines the quality of the hay based on the idea of potential-digestible dry matter intake of the hay. Fiber will often lower the RFV index of the hay. Grass hays are typically higher in fiber than alfalfa.[4] However, RFV is not included in the analysis due to not being a popular quality measure at the hay auction. Total digestible nutrients (TDN) is a measure of the total digestible nutrients in the hay or the energy value of the hay. TDN values range from 40 to 55 percent.[5]

[4] www.stearnsdhialab.com/whatis.html
[5] Nadeau, Jennifer. "Hay Analysis: Its Importance and Interpretation." Extension Article. 27 Oct. 2014.

Table 1 provides descriptive statistics for forage types, form, value and year. As can be seen in the table, at 51% of the total species, Mixed Grass hay is the most prominent species sold over the five observed years at the hay auction. Square bales represented 61% of the hay sold whereas only 39% of hay sold in the form of round bales. Most of the hay sold was in 2014 at 29%. One last thing to point out is that 42% of the hay sold was of medium quality based on its TDN value.

Table 1. Descriptive Statistics - Forage Types, Form, Value and Year
206 Total Observations

	Total Observation	% of Total
Alfalfa Mix	47	23%
Mixed Grass	106	51%
Other	53	26%
Round	80	39%
Square	126	61%
2012	26	13%
2013	48	23%
2014	59	29%
2015	32	16%
2016	41	20%
High	59	29%
Medium	86	42%
Low	61	30%

In Table 2, the average price per ton for round bales is $66.61 with an average weight of 854.19 pounds. The largest lot size of round bales contained 91 bales. From Table 3, square bales average price per ton is $225.83 with an average weight of 44.99 pounds. Square bale's largest lot size contained 420 bales.

Table. 2 Descriptive Statistics - Round Bales

Variable	Mean	St. Deviation	Low	High
Price per ton	$ 66.61	$ 33.90	$ 14.99	$ 173.33
Bale weight (lbs)	854.19	253.48	354	1541
Lot Size (# of bales)	13.08	12.53	1	91
TDN	40.77	8.28	9.6	60.51
Crude Protein	7.8	3.76	0.39	18.72

Table. 3 Descriptive Statistics - Square Bales				
Variable	Mean	St. Deviation	Low	High
Price per ton	$ 225.83	$ 59.77	$ 75.49	$ 380.00
Bale weight (lbs)	44.99	6.61	27	60
Lot Size (# of bales)	136.67	85.5	3	420
TDN	49.99	7.29	35.1	43.97
Crude Protein	11.25	5.18	2.29	21.33

Methodology

This paper uses the data from the Central Kentucky hay auction to analyze hay price using a hedonic model. The model will be estimated to explain hay price using the following dependent variables: type of hay, number of bales sold in a single lot, square versus round, weight of hay, quality measures of hay (crude protein and TDN), total precipitation, average temperature and live cattle futures. Ordinary Least Squares (OLS) estimation will provide the results of the model. Other tests will be performed to account for multicollinearity and heteroskedasticity. All models and tests will be performed using Statistical Analysis System (SAS). The results of the analysis will shed some light on how much premiums are received for square bales versus round bales. The impact that quality measures and forage species have on the market value of hay in the location studied will also be determined.

Model

In the initial model, heteroskedasiticity was a problem but was resolved by using a deflated price per ton. As in McCullock et al. (2014), the price per ton is deflated by using the USDA-NASS's (2006-2016) monthly feed index published in the monthly Agricultural Prices report, with the base year being 2015. The following equation is the linear model used for the analysis:

$$Hay\ price = \beta_0 + \beta_1 Alfalfa\ Mix + \beta_2 Timothy, Orchard, Clover + \beta_3 Live\ Cattle\ Futures$$
$$+ \beta_4 Temperature + \beta_5 Temperature^2 + \beta_6 Total\ Precipitation + \beta_7 Round\ Crude$$
$$+ \beta_8 Square\ Crude + \beta_9 Square\ Bale\ Weight + \beta_{10} Round\ Bale\ Weight$$
$$+ \beta_{11} Round\ Lot\ Size + \beta_{12} Square\ Lot\ Size + \beta_{13} Square\ High$$
$$+ \beta_{14} Square\ Medium + \beta_{15} Square\ Low + \beta_{16} Round\ High + \beta_{17} Round\ Medium$$

Table 5 provides an explanation of the variables used in the model. Square bales are not included in the actual regression due to preference. Low quality hay is not included in the regression in order to interpret the results as premiums versus discounts. Mixed Grass is left out in order to interpret Alfalfa Mix and Timothy, Orchard and Clover to compare those variables to Mixed Grass.

Table 5: Explanation of Variables

Hay Price	Deflated price per ton received for each lot of hay
Mixed Grass	Binomial variable, 1 if Mixed Grass, 0 if otherwise
Alfalfa Mix	Binomial variable, 1 if Alfalfa Mix, 0 if otherwise
Timothy, Orchard, Clover	Binomial variable, 1 if Timothy, Orchard, Clover, 0 if otherwise
Temperature	The average temperature for Madison County during the production year time period April-August
Live Cattle Futures	The February Future price for the month of January
Total Precipitation	The total precipitation for Madison County during the production year time period April-August
Round	Binomial variable, 1 if round, 0 if otherwise
Square	Binomial variable, 1 if square, 0 if otherwise
Round Crude	Interaction term between Round bale and Crude Protein
Square Crude	Interaction term between Square bale and Crude Protein
Round Bale Weight	Interaction term between Round bale and Bale weight
Square Bale Weight	Interaction term between Square bale and Bale weight
Round Lot Size	Interaction term between Round bale and Lot Size
Square Lot Size	Interaction term between Square bale and Lot Size
Round High	Interaction term between Round bale and High quality hay
Round Medium	Interaction term between Round bale and Medium quality hay
Round Low	Interaction term between Round bale and Low quality hay
Square High	Interaction term between Square bale and High quality hay
Square Medium	Interaction term between Square bale and Medium quality hay
Square Low	Interaction term between Square bale and Low quality hay

Results

The results of the regression are displayed in Table 6. The model explained 90% of variation in the hay auction prices. With the baseline for the regression equation being Mixed Grass hay, Alfalfa mix and Timothy, Orchard, Clover are significant at the 95% significance level and offered premiums to mixed grass hay. Alfalfa mix hay will bring $23.50 per ton more than mixed grass hay, while Timothy, Orchard, Clover hay types will bring $14.79 per ton more than mixed grass hay, ceteris paribus and measured at sample mean.

All interaction terms of quality level and bale type were significant in the regression, with a baseline of the Round*Low interaction term. This result was similar to that of McCullock et al. (2014), where all grades (Good, Premium, Supreme and Utility) and interaction terms were significant in each regression of that paper and the higher the grade, the higher the premium. As expected, the interaction terms between square bales and quality resulted in high premiums versus round bales. High quality square bales had a premium of $304.79 per ton than that of low quality round bales, with decreasing premiums with lower quality hay. High quality round bales had a premium of $27.40 per ton versus low quality round bales. Crude protein is significant with positive coefficients for both round and square bales. A 1% increase in crude protein increases the price of square bales by $4.50 per ton, whereas, it only increases round bales by $2.28 per ton. Premiums for higher quality hay are related to buyers who are concerned with the nutritional value of the hay that is being fed to their livestock.

The bale weight for square bales is significant in influencing the price of hay, in that a one-pound increase in square bales will result in a discount of $3.30. When examining the marginal effect of bale weight on square bale price, it is determined that the marginal value of square bales decreases with additional pounds. For example, the actual average weight of a square bale from the data set is 45 lbs with an average price of $226 per ton, or $5.09 per bale. If the weight of the bale is increased to 46 lbs, the price per ton is $222.70 per ton, or $5.12 per bale. This is only a $0.03/bale or $60/ton increase for one additional pound, meaning that as the weight of square bales increase, there is not much increase in price received for that bale.

There is weak evidence that the size of the lot for round bales has influence on the hay price. However, lot size for square bales was significant, with discounts as lot size increases. Live cattle futures did have some impact on price per ton, revealing that as live cattle futures increase, the price of hay increases as well. Although not significant in the regression, temperature and precipitation were included to account for effects on yield and quality of hay. Temperature should have some effect on quality as higher temperatures will dry out hay faster and could decrease the quality and moisture contents. Total precipitation can effect when hay can by harvested. If the production period is met with a substantial amount of precipitation, it can make it harder for the producer to harvest and can also cause a decrease in quality the longer the hay sits. Note that while precipitation was not significant at the 90% level, it was extremely close to being significant and the negative sign is consistent with expectations.

Table. 6 Regression results for Hay Price/Ton

Parameter Estimates		
Variable	**Parameter Estimate**	**Standard Error**
Intercept	-135651	117808
Alfalfa Mix	23.50447***	9.54851
Timothy, Orchard, Clover	14.79017***	5.89342
Temperature	3985.95936	3480.51204
Temperature2	-29.28323	25.67729
Live Cattle Futures	1.12207*	0.65011
Total Precipitation	-3.07143	1.99563
Round*Crude	2.28477**	1.14684
Square*Crude	4.50864***	1.27302
Square*Bale Weight	-3.30425***	0.62844
Round*Bale Weight	-0.01484	0.01189
Round*Lot Size	0.21476	0.24535
Square*Lot Size	-0.08854**	0.04418
Square*High	304.78545***	35.2578
Square*Medium	280.32138***	31.63377
Round*High	27.4036**	12.34572
Round*Medium	14.8548**	7.09173
Square*Low	240.13897***	35.7779

***Estimate significant at the .01 probability level
**Estimate significant at the .05 probability level
*Estimate significant at the .10 probability level

Conclusion

The results prove that the hypothesis is correct in that quality would be an important factor in determining hay price. Quality factors were found to be generally more important in square bales than in round bales. This may be because the market for small square bales in this instance is primarily horse owners, who purchase square bales due to ease of handling, and may be more concerned with what they are feeding their horse versus beef producers. At all three quality levels, square bales offer a premium of more than $200 per ton. There is also evidence to suggest that there is a negative relationship between the bale weight for both square and round bales and the price per ton, with price per ton being more robust for square bales. It may be possible that square bales can simply become too heavy and producers are likely better off to market a larger number of smaller square bales.

Alfalfa mix hay and hay that is either Timothy, Orchard or Clover will receive premiums over that of mixed grass hay, which is most likely due to having higher quality levels than mixed grass. The lot size of round bales does not have a significant effect on hay price received, but larger lot sizes of small squares were found to be associated with lower price levels. Precipitation and temperature did not influence the price of hay in this regression model, though they are still important factors in the production of hay.

Due to the fact that little research has been conducted in the area of hay production and marketing, this work adds to the existing literature and can be used as a basis for further research in this area. Based on the findings of this research, farmers could decide to make changes in what type of hay they chose to feed their livestock based on how the quality measures of hay impact the price in order to cut costs. Hay producers could make changes to what type and how they chose to produce and market hay in order to increase their profits. These changes could be switching from a species of hay that has less influence on price, to one that has a larger impact. Due to square bales having such drastic impacts on the price of hay, producers may choose to switch from round bales to square bales as a way to increase returns. Ultimately, the producer will make their production and marketing decisions based on what fits

best with their operation. The results of this analysis will simply give the producers more information about how different characteristics of hay have the most influence on the price of hay received at auction.

References

Crop Production 2015 Summary. USDA, National Agricultural Statistics Service. January 2016.

Kentucky Agriculture Facts. Second Edition. Kentucky Farm Bureau. Sources: National Agricultural Statistics Service and Census of Agriculture, 2012, total sales including stud fees.

Grisley, B., Stefanou, S., and Dickerson, T. "Factors Affecting the Price of Hay at a Pennsylvania Auction." *Northeastern Journal of Agricultural and Resource Economics*. 14, 1(1985).

Lacefield et al., "Quality Hay Produciton." AGR-62. University of Kentucky College of Agriculture.

Livestock Marketing Information Center. 2016. Live Cattle Futures.

McCullock et al., "Price Characteristics at a Hay Auction." *Agronomy Journal*. Volume 106, Issue 2. Mar. 6, 2014.

Nadeau, Jennifer. "Hay Analysis: Its Importance and Interpretation." Extension Article. 27 Oct. 2014.

Rudstrom, Margaretha. "Determining Implicit Prices for Hay Quality and Bale Characteristics." *Review of Agricultural Economics.* 26, 4(2004):552-562.

Yeboah, Godfred and Lawrence, John. "Estimating the Value of Source Verification in Iowa Feeder Cattle Markets." A.S. Leaflet R1725. Iowa State University.

Zimmerman et al., "The Effect of Value-Added Management on Calf Prices at Superior Livestock Auction Video Markets." 2012. *Journal of Agricultural and Resource Economics*. 37(1):128-143.