INFLUENCE OF QUALITY AND SEASON ON HAY MARKET DECISIONS

Russell Tronstad and Satheesh Aradhyula[i]

ABSTRACT

Price differentials for hay are driven by variations in location, quality, and season. We model hay prices using a local market (Yuma, AZ) for three alfalfa qualities. Seasonality in the mean and variance for high, low, and off-grade quality hay were modeled using polynomial functions and a trivariate conditional error structure. Results indicate that both conditional means and variances exhibit strong seasonality patterns that reflect local supply and demand factors. Although seasonality in the mean followed a similar pattern for all hay qualities, conditional variance seasonality patterns were quite different. Results have implications for accurate risk and market assessments for producing, buying, storing, and selling alfalfa.

Key words: alfalfa, dairy, shipping costs, simultaneous, static seasonality

INTRODUCTION

Hay is an important crop for the U.S. with a farm value of $12.3 billion in 2003, second only to corn and soybeans. The 63.3 million acres of all hay harvested in the U.S. comes close to rivaling the acreage of corn and soybeans, as described in figure 1. Yet relatively little market research has been conducted for alfalfa relative to other major field crops of corn, cotton, soybeans, and wheat. This is largely due to the local and seasonal nature of supply and demand factors that determine alfalfa prices. The bulky nature of alfalfa makes it difficult to transport supplies from one region to another. To illustrate this bulkiness, corn was 3.95 times more valuable than alfalfa on a volume basis for 2003, yet alfalfa sold for a little more than corn by weight, 4.65 versus 4.37 cents per pound. Using representative shipping costs as described in table 1, the ground shipping distance needed to equal the average U.S. farm price for alfalfa, wheat, corn, soybeans, and cotton equals 929, 3655, 2673, 7,909, and 12,760 miles, respectively. These shipping distances also correlate with the amount of U.S. production that is exported of these commodities. For example, around 70% of the U.S. cotton crop was exported last year while less than 20% of the corn crop and around 1% of the U.S. hay crop, including meal and cubes, was exported. ERS/USDA estimates that about 70% of hay production is consumed on farms and ranches where it is grown (Shields and Baker). But this number has declined from around 80% in the late 1970's. Niche markets that service large dairies and pleasure horse owners have contributed to the increase in utilizing hay away from the farm where it was produced.

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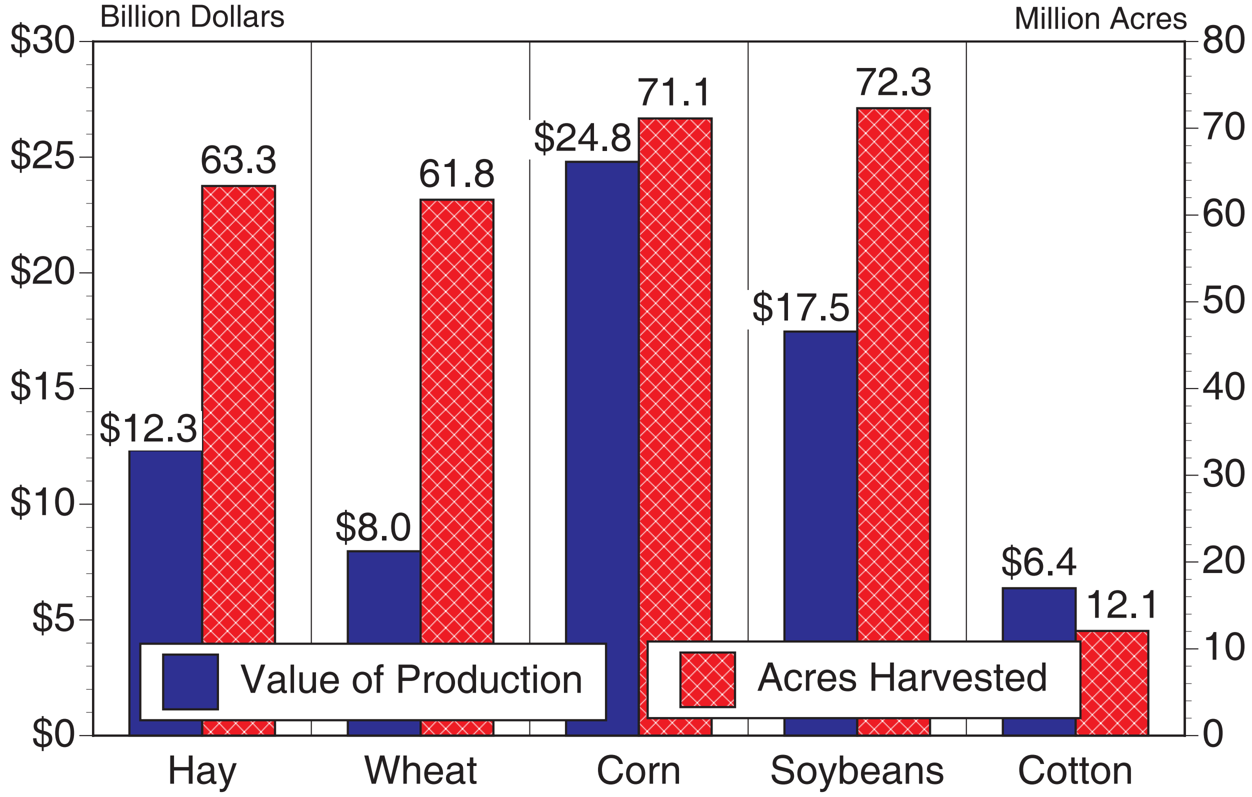
Figure 1. Value and acreage of selected field crops in the U.S., 2003



Source: Agricultural Statistics, 2004

Table 1. Relative Values and Ground Shipping Costs of Selected Commodities, 2003

	Alfalfa	**Wheat**	**Corn**	**Soybeans**	**Cotton**
2003 U.S. average farm price	$92.90/ton	$3.35/bu.	$2.45/bu.	$7.25/bu.	63.8 ¢/lb.
Relative Values					
by weight (¢/lb.)	4.65	5.58	4.37	12.08	63.8
by volume ($/ft^3)	0.58	3.13	2.29	6.78	18.77
Shipping distance to equal farm value of commodity[a]					
ground miles	929	3,655	2,673	7,909	12,760
shipping method	truck	rail	rail	rail	truck

[a] Rail shipping cost of $1.65/bu. for each 1,800 miles transported. Truck shipping cost of $ 2.50 per loaded mile for a 50,000 lb. truck load.

Most economic time series exhibit seasonal variation or cyclical patterns and alfalfa prices are no exception. Alfalfa supplies reach their peak at the end of the summer harvest season while demand for livestock feeding is greater during the winter than summer months. These combined seasonal supply and demand factors result in seasonal alfalfa price patterns (Bliss and Ward). In addition, the time lag associated with bringing alfalfa into full production, the localized nature of alfalfa markets, and uncertainties surrounding quality degradation from hay placed in storage make alfalfa prices richer in seasonality than most commodities. Because of these uncertainties and inherent seasonality, risk management and market timing decisions for alfalfa producers depend on accurate seasonal mean and variance information of prices.

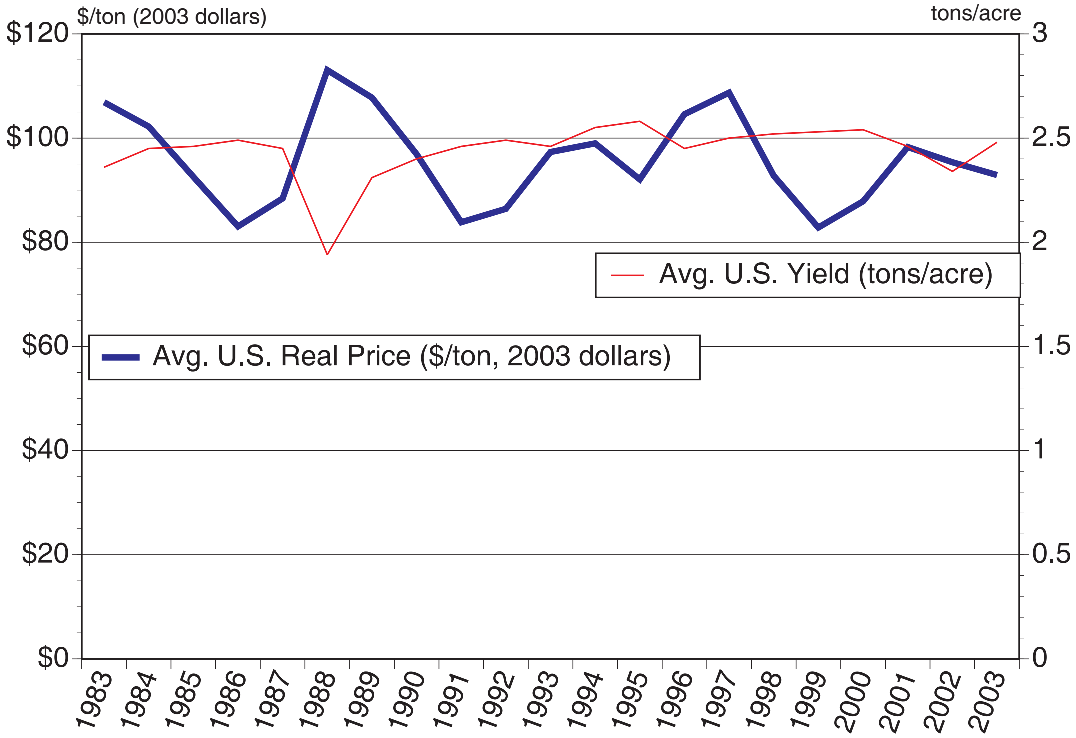
MODELING AND DATA CONSIDERATIONS

Average U.S. hay yields have been remarkably flat for the last two decades as described in figure 2, so it is not surprising that real hay prices have also been fairly level with no statistically significant trend. In comparison, technology gains for corn production over this period have resulted in a steady upward yield trend of almost 2 bu./acre for each year. This upward trend has placed downward pressure on corn prices as described in figure 3. On average, each bushel increase in corn yield has translated into about a 3.3 ¢/bu. price decline.

Given that roundup ready alfalfa is coming on-line for commercial use, some believe that this will greatly enhance the profitability of alfalfa producers. But higher hay yields from roundup ready alfalfa will likely result in downward price pressure as they have for corn. Higher yields and supplies for a region result in lower prices, and both adopting and non-adopting producers will face lower alfalfa prices, ceteris paribus. Whether a producer should adopt the technology or not still depends on expected yield and quality-price benefits relative to the cost of the technology. Because alfalfa is a perennial crop with multi-year benefits, conservative price levels and premiums for weed-free quality should be used in evaluating the benefits of round-up ready technology for more distant years.

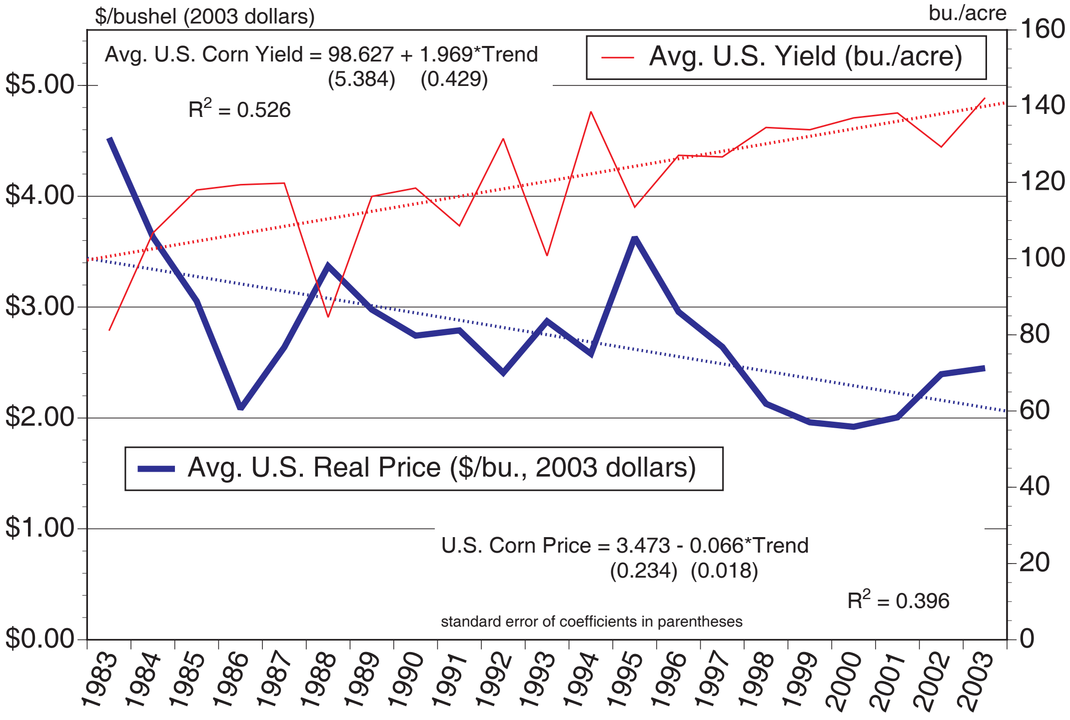
To reinforce that hay is largely a local market, figure 4 displays how average hay prices can vary three-fold between different states. For example, in 2003 the average farm price received for all hay in Mississippi was only $42.5/ton while it was $150/ton in Maryland. This extreme variation in price between different states highlights the difficulty of shipping hay from a “surplus” to “deficit” region. But a large portion of the price variation between states is also related to quality differences. That is, states with high dairy to feedlot cattle ratios (e.g., Northeastern states) produce a larger percentage of high quality alfalfa than states like Nebraska where many large feedlots reside. Like hay, corn prices are also higher for states with relatively large dairy to feedlot cattle numbers. However, the slope of this estimated relationship is 200 times less for corn than alfalfa (.061 versus 12.205), as described in figure 5. The relatively narrow range in corn prices across state lines, varying from $2.25 to $3.20, also reflects that corn can be transported much more easily than hay and that it is also a more homogenous quality feed product.

Figure 2. U.S. average hay prices and yields, 1983-2003



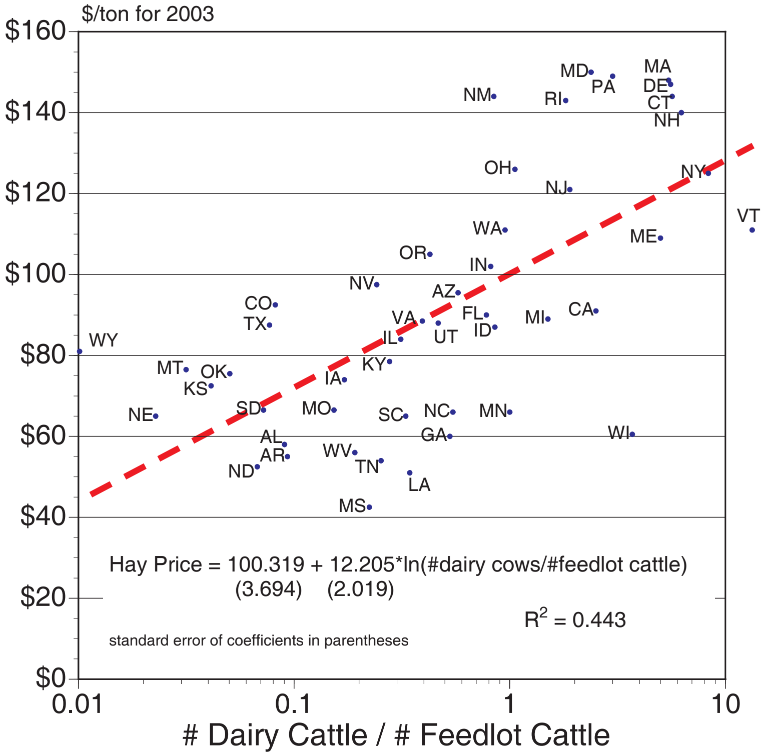
Source: USDA/NASS

Figure 3. U.S. average corn prices and yields, 1983-2003



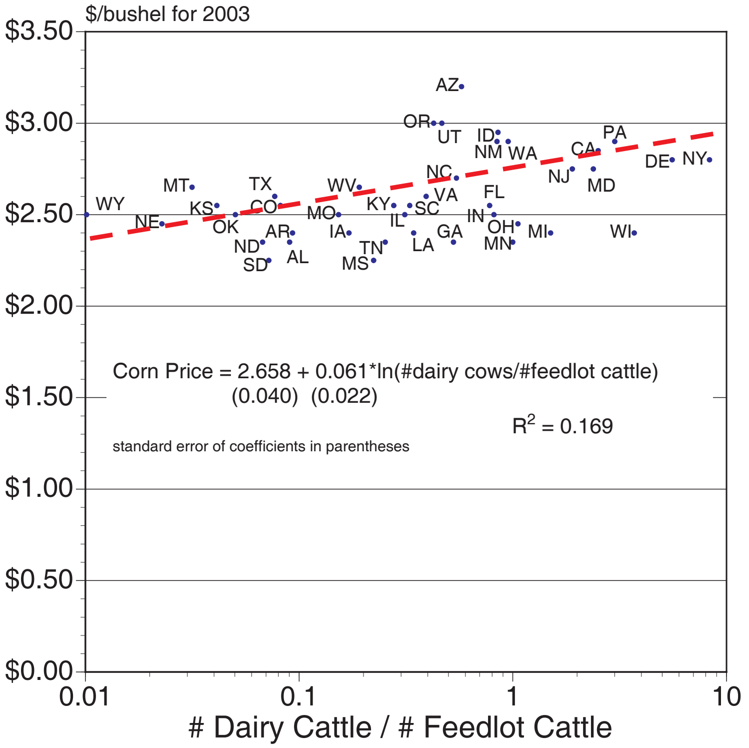
Source: USDA/NASS

Figure 4. Average state hay prices relative to their dairy/feedlot cattle numbers



Source: USDA/NASS

Figure 5. Average state corn prices relative to their dairy/feedlot cattle numbers



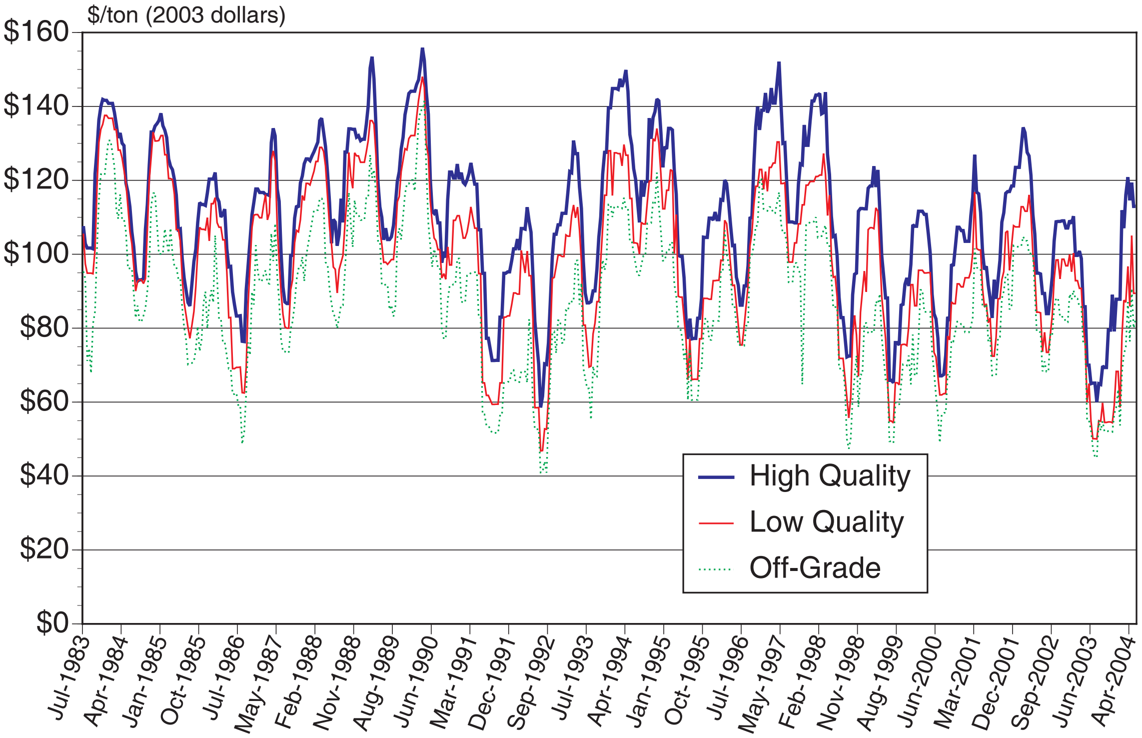
Source: USDA/NASS

To analyze both quality and seasonal factors for a local hay market, we collected prices from the *Arizona Alfalfa Market Report* for Yuma County, Arizona for the three alfalfa qualities reported of "high," "low," and "off-grade." Prices from July 4, 1983 through May 18, 2004 are analyzed. Because the report switched from a weekly to bi-weekly frequency after November 7, 1993, weekly prices were made into bi-weekly prices. The mid-point between weekly high and low prices was used to represent bi-week prices. This is also what was used if a price range was reported for a given quality in a bi-weekly report. The time period considered includes 544 bi-weeks or almost 22 years of data. Reported hay prices were deflated by the monthly Producer Price Index, all commodities, agriculture (US Dept. of Labor, Bureau of Labor Statistics).

Hay prices are reported in dollars/roadside ton. Harvest of alfalfa hay in Yuma county begins around the end of February and continues until mid-November. Growers in Yuma county harvest 10-12 cuttings of alfalfa each year with an annual yield of 8.85 tons/acre (average 2001-03 yields). The first and latter cuttings of the year are light in yield, often less than .5 tons/acre. But these cuttings offer some of the highest protein for the year so that this hay usually commands a premium from dairies. "Low quality" alfalfa primarily goes to feedlots in the area or to retail livestock feed stores. "Off-grade" alfalfa has more weeds and grasses than the "high" or "low" quality grades and could be discolored some from rainfall.

Figure 6 graphically portrays the inflation adjusted or real bi-weekly prices for the period considered. Two items are clearly revealed in this chart. First, prices have a very systematic seasonal pattern. The number of years considered can be determined by simply counting the

Figure 6. Bi-weekly Yuma, AZ real alfalfa prices, 4 July 1983 through 18 May 2004



peaks or troughs in prices. Second, all three hay qualities tend to follow each other so that an estimation procedure needs to jointly consider all three qualities. Thus, alfalfa prices were jointly modeled for the three hay qualities as

$$(1)\qquad (1-\sum_{j=1}^{k}\gamma_{ij}\mathrm{L}^{j})(1-\mathrm{L})(P_{it}-S_{it}^{p}) = e_{it} \qquad\qquad \text{i=1,2,3}$$

where, P_{it} is the price of alfalfa for quality *i* in week *t*, L is the lag operator, γ_{ij} are coefficients associated with lagged price differences, S_{it}^{p} is seasonality of the mean price associated with quality *i* ("high," "low," and "off-grade") and e_{it} is the error term.

Seasonality was modeled as a polynomial function,

$$(2)\qquad S_{it}^{p} = a_{i1}w_t + a_{i2}w_t^2 + a_{i3}w_t^3 + \cdots + a_{iq}w_t^q,$$

$$\sum_{j=1}^{q} a_{ij} = 0, \quad \text{and} \quad \sum_{j=2}^{q} ja_{ij} = 0, \qquad\qquad \text{i=1,2,3}$$

where, w_{t} is defined as the calendar bi-week of the year divided by 26, a_{ij} are the unknown parameters, and *q* is the order of the polynomial. w_{t} is a time index that cycles between 0 and 1 and in order for the seasonality cycles to be continuous, parameters in (2) should satisfy the condition $\sum_{j=1}^{q} a_{ij} = 0$ or $S_i^p(0) = S_i^p(1)$.[1] In addition, parameters should also satisfy conditions so that seasonality is smooth or that the slope at $S_i^p(0)$ equals the slope of $S_i^p(0)$ (i.e., $S_i^p{}'(0) = S_i^p{}'(1)$ or $\sum_{j=2}^{q} ja_{ij} = 0$).

The innovations in (1) are assumed to follow a multivariate AutoRegressive Conditional Heteroskedastic (ARCH) process. Several parameterizations have been suggested to specify the conditional variance-covariance matrix $\mathbf{H}_{\mathrm{t}}$ in an ARCH process. These include a linear diagonal model in Bollerslev, Engle, and Wooldridge, latent factor ARCH model in Diebold and Nerlove, positive semi-definite model by Baillie and Myers, full vech specification by Moschini and Aradhyula and constant conditional correlations model by Bollerslev. We focus on the latter method because it represents a major reduction in computational complexity. Bollerslev's model allows for time-varying conditional variances and covariances, but assumes constant conditional correlations.

Allowing for seasonality, the conditional variances and covariances under multivariate ARCH are then specified as,

$$(3)\qquad \mathbf{e}_t|\Omega_{t-1} \sim t\left[\begin{pmatrix}0\\0\\0\end{pmatrix}, \mathbf{H}_t\right], \qquad\qquad \mathbf{H}_t = \begin{bmatrix} h_{11t} & h_{12t} & h_{13t} \\ h_{21t} & h_{22t} & h_{23t} \\ h_{31t} & h_{32t} & h_{33t} \end{bmatrix}$$

$$\begin{aligned} h_{iit} &= \alpha_i + \sum_{j=1}^{m} \alpha_{ij} e^2_{i,t-j} + S^h_{it} && i=1,2,3 \\ h_{ijt} &= \rho_{ij}\sqrt{h_{iit}h_{jjt}} && i \neq j \quad i,j=1,2,3 \end{aligned} \tag{4}$$

where, Ω_{t-1} is the set of all information available at time t, h_{iit} is the conditional variance of the ith quality hay at time t, and h_{ijt} is the conditional covariance between the ith and jth quality of hay at time t, α_i, α_{ij}, and ρ_{ij} are unknown parameters and S^h_{it} describes the seasonality in h_{ijt}. ρ_{ij} is the time-invariant correlation coefficient between i^{th} and j^{th} quality hay prices.

Several different specifications might be used to specify the seasonal component, S^h_{it}, in the conditional variance equation. Martinez and Zering and Yang and Brorsen, for example, used sine and cosine terms to model seasonality. As in the mean equation, we use a polynomial function to describe the seasonality in conditional variances:

$$\begin{aligned} &S^h_{it} = \exp\{c_{i1}w_t + c_{i2}w_t^2 + \cdots + c_{is}w_t^s\}, \\ &\sum_{j=1}^{s} c_{ij} = 0, \text{ and } \sum_{j=2}^{s} jc_{ij} = 0, \qquad i=1,2,3 \end{aligned} \tag{5}$$

where, c_{ij} are unknown parameters, and s is the order of the polynomial. As with seasonality in the mean equation, the sum of all polynomial coefficients was set equal to zero to ensure continuity (i.e., $S^h_i(0) = S^h_i(1)$) and smoothness of seasonal volatility was ensured by setting the slope of $S^h_i(0)$ equal to the slope of $S^h_i(0)$ (i.e., $S^h_i{}'(0) = S^h_i{}'(1)$). Seasonality was specified in exponential form to ensure positive conditional variances.

ESTIMATED RESULTS

Full Information Maximum Likelihood estimates of parameters in equations (1) through (7) along with summary statistics are reported in table 2. Using the Schwarz Bayesian Information Criteria (BIC) to determine appropriate polynomial and lag orders, a polynomial of order seven was found to most adequately represent mean price seasonality. These parameter estimates make up the price seasonality (unconditional mean) patterns described in figure 7 for all three hay qualities. Using the average of all first bi-weeks as a starting point, “high quality” prices begin the year at \$121 and gradually increase to a peak of \$127 by the end of March. Then prices decline quite sharply to reach a low of about \$87 by the last week of July. Prices then increase steadily, almost mirroring the rate of decline, to reach \$120 by the first week of December. Long-term averages for “low” and “off-grade” qualities during the first bi-week of January are \$107 and \$93 per ton. Following a similar seasonal pattern to “high quality,” “low” and “off-grade” qualities increase to \$114 and \$99 by the end of March and then dip to \$75 and \$68 by the end of July. The dip in prices during the late summer months corresponds to when production is greatest in tons/cutting or tons/month. “High” and “low” qualities have a larger estimated price spread between their peaks and troughs than “off-grade” quality (i.e., \$40 and \$39 versus \$31). This

Table 2. Maximum Likelihood Estimates of Trivariate ARCH Model

Coef-	High Quality		Low Quality		Off-Grade	
icients	estimate	std. error	estimate	std. error	estimate	std. error
Mean Equation						
γ_{i1}	-0.2627	0.0416	-0.3374	0.0370	-0.2871	0.0345
γ_{i2}	-0.1050	0.0394	-0.2563	0.0428	-0.1562	0.0396
γ_{i3}	-0.0842	0.0409	-0.0857	0.0282	-0.0943	0.0351
seasonality coefficients for mean price						
a_{i3}	4767.6	2600.3	4992.6	2476.5	2943.02	3292.1
a_{i4}	-24282.1	7566.0	-25265.4	7158.4	-17212.8	9534.6
a_{i5}	47170.4	11223.0	48932.4	10615.2	34284.1	14155.1
a_{i6}	-39383.6	8218.1	-40858.4	7792.0	-28713.5	10401.8
a_{i7}	11973.6	2356.2	12443.6	2241.6	8696.6	2995.89
Variance Equation						
α_{i1}			0.0567	0.0329	-0.0011	0.0329
α_{i2}			0.2742	0.0501	0.0940	0.0501
α_{i3}	21.279	2.223	17.688	2.226	27.588	3.491
seasonality coefficients for variance						
c_{i2}	51.546	24.360	55.089	27.175	90.193	26.902
c_{i4}			-107.513	7.615	-61.674	20.166
Estimated Correlations (ρ_{ij} s)						
high	1.000		0.645	0.0364	0.502	0.0390
low			1.000		0.661	0.0319
off-grade					1.000	
Summary Statistics[a]						
MAPE	3.447		4.419		5.396	
R^2	0.973		0.968		0.952	

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[a] MAPE is mean absolute percent error. R^2 is the squared correlation coefficient between actual and one period ahead estimated prices.

smaller spread for "off-grade" is attributed to little or minimal demand for crude protein and other relative feed value attributes, which erode during the hottest summer months, compared to the demand for these attributes from "high" and "low" quality hay buyers.

Figure 8 graphically portrays the unconditional seasonal standard deviations or a measure that reflects seasonal price volatility. Appropriate polynomial orders for seasonality in the variance equation were identified as a fourth-order for "low" and "off-grade" qualities and a third-order for "high" quality. "High quality" is essentially flat in volatility around \$4.6/ton for most of the year with a slight increase to \$5.1/ton by end of September before gradually returning to around \$4.6/ton in January. "Low" and "off-grade" qualities follow a similar price volatility pattern of

Figure 7. Estimated unconditional mean price seasonality

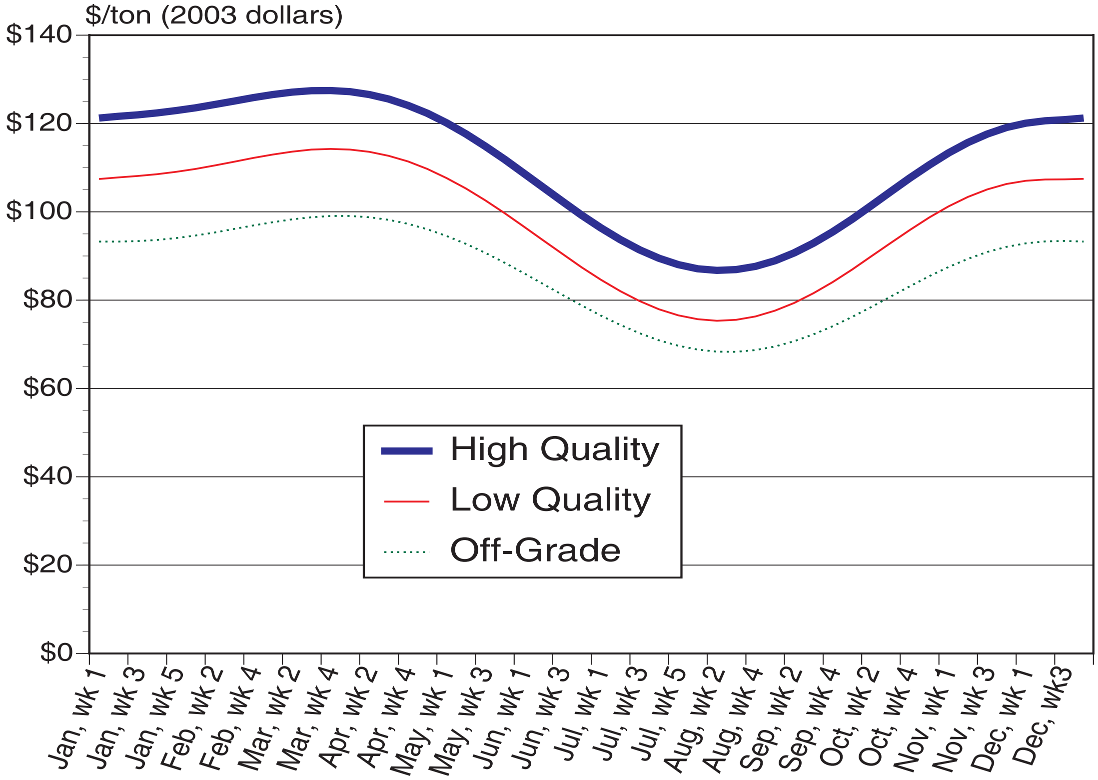
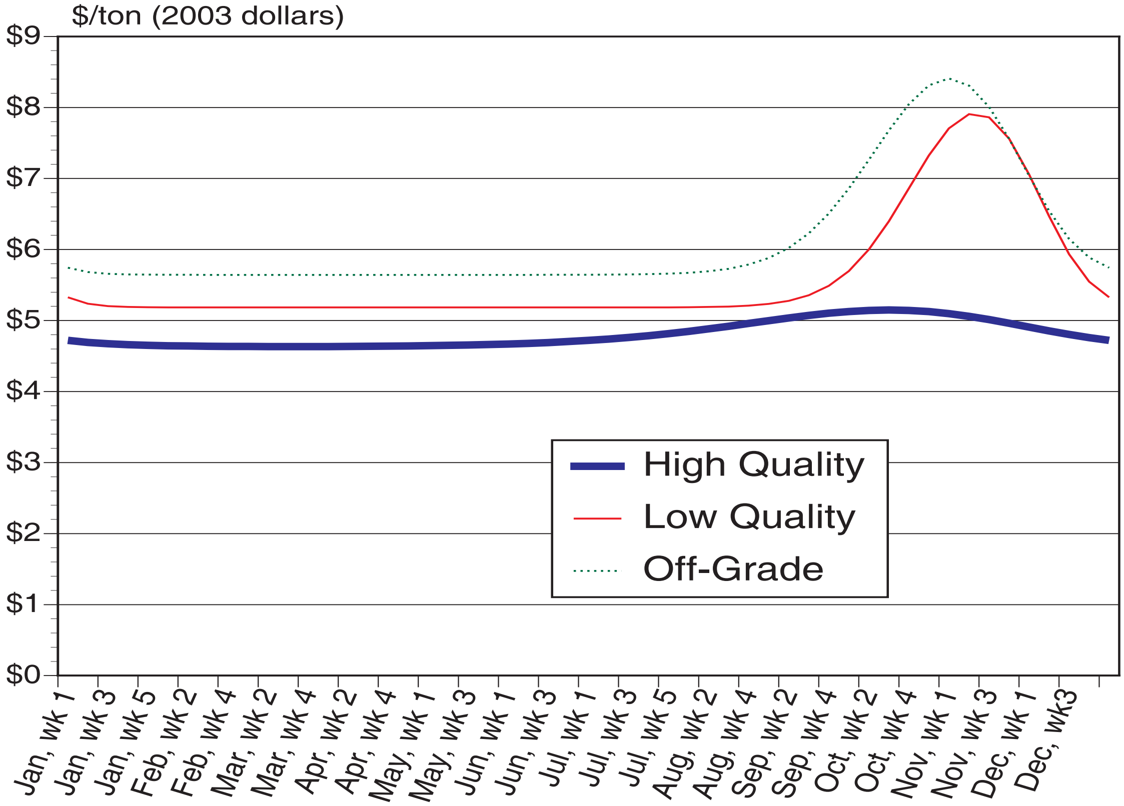


Figure 8. Estimated unconditional seasonal standard deviations



being essentially flat from the beginning of the year until the end of August. After hay prices have reached their seasonal low for the year and start to increase, volatility then spikes upwards. "Off-grade" reaches a peak in its estimated standard deviation of $8.4/ton by the first week of November, almost double the $5.6/ton that it is flat at for most of the year. "Low" quality reaches a peak of $7.9/ton by the second week of November, one week later than "off-grade" before dropping to its flat level of $5.2/ton by the second week of January. These volatility measures have implications for hay marketing decisions. For example, greater volatility from the end of August through the first of January for "low" and "off-grade" hay prices implies that prices for these qualities have a greater propensity of returning to their long-term seasonal mean price (i.e., figure 7) than during the rest of the year. Thus, if prices for "low" and "off-grade" are **less than** their seasonal lows of $75 and $68 per ton during the end of July and first weeks of August, placing hay in storage then has a greater chance of paying off than at any other time. That is, mean prices are on an upward seasonal pattern at this time and the increase in volatility that follows implies that prices have a greater chance of returning to their seasonal mean than at any other time of the year.

In general, hay storage has the least chance of paying off after the first week of April. This period is before production starts to increase with higher quantities produced each month and volatility is essentially flat. However, this does not imply that storage will never pay-off for this period. An unconditional standard deviation of $5/ton, implies that prices will fall within $5/ton above or below the estimated conditional seasonal mean price about 2/3rds of the time. Thus, if prices are currently $90/ton and expected to increase by $1/ton at the next bi-week, due to seasonal price patterns (e.g., figure 7), we would expect prices to be between $86 and $96 per ton about 2/3rds of the time. This price range is fairly substantial in percentage terms. Given that the variance of "off-grade" always exceeds the other qualities and it also has the lowest mean price, "off-grade" has greater absolute and percentage price fluctuations than the other qualities. Part of this volatility may be explained by more variation within "off-grade" hay sales than the other qualities. In addition, moisture damage to alfalfa in the windrow could cause a large influx of alfalfa to move into the "off-grade" category and precipitate a sharp price drop. "Low" quality price volatility falls between "off-grade" and "high" quality. The relatively stable demand for "high" quality alfalfa attributes from dairies is why high quality is believed to have the lowest price variability. In addition, "high" quality can easily be substituted for "low" and "off-grade" markets whereas "off-grade" has virtually no substitution for the "high" quality dairy market.

To summarize statistical properties of the models, all parameters associated with seasonality in both mean and variance equations are statistically significant with few exceptions. The third-order polynomial parameter for mean "off-grade" price seasonality (a_{33}), the fourth-order polynomial variance term for "low" quality (c_{i4}), and the first-order ARCH parameter for "off-grade" (α_{31}) are not significant at a 10 percent level. Additionally, in each h_{it} equation, estimated ARCH parameters are between zero and one and add to less than one, indicating that the underlying unconditional variances exist. All three estimated conditional correlation coefficients are significant at even the .001 level, suggesting that there are very important interrelations among the three hay qualities. Low sample mean absolute percent errors (all less than 5.4 percent) and high R^2 values (all greater than .95) indicate that the estimated models do a reasonable job of tracking price levels.

Results illustrate that seasonality in the mean can be very similar for three related prices while variance information is quite different. Traditional methods of limiting attention to just the mean can confine our understanding of price relationships and lead to inferior marketing decisions. We hope that the results of this research will persuade others to more thoroughly examine conditional variances and use less limiting methods than what have traditionally been embraced for analyzing seasonality of time series data.

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