A Linked Annual and Monthly Model for Forecasting Alfalfa Hay Prices

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This article develops a model to forecast monthly alfalfa hay prices before the first harvest. This is done by linking an annual model, which forecasts the initial May price, with a system of monthly equations that track the monthly seasonal price pattern, given the forecasted May price.

In much of the western United States, alfalfa hay is a cash crop. Before the first cutting each year, growers and users of alfalfa hay spend considerable time and effort gathering information to help establish their initial price offers. Buyers contact other buyers and sellers, and sellers do the same as they try to arrive at mutually agreeable prices.

Currently, neither annual nor monthly forecasts of New Mexico alfalfa hay prices are published before the first cutting. Such forecasts would help producers and users of alfalfa hay plan their operations for the coming year. These forecasts would also be an independent information source that users and growers could use in the process of price discovery. The forecasts can also be the basis to initiate more formal price negotiations. This article develops a model for forecasting monthly alfalfa hay prices for the season, before the first harvest.

The level of alfalfa hay prices has been volatile while the seasonal price pattern has remained fairly stable. Under these conditions, determining prices can be viewed as a two-step procedure. The first step is to forecast that point from which the seasonal price pattern starts. This was done using an annual model. The second step is to identify the seasonal price pattern. In this article, this was done using a system of monthly equations. Linking the annual model with the monthly price forecasting relationships incorporates both these elements of the price determination process in forecasting monthly alfalfa hay prices.

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Literature

No published studies to forecast alfalfa hay prices were found. Although an important input in beef, dairy and horse production, alfalfa hay price forecasting has received scant attention in the literature. Only one unpublished study by Myer and Yanagida was found on this topic.* They combined an annual econometric model with a quarterly ARIMA model to forecast quarterly alfalfa hay prices in the 11-state western region.

Annual Model

Forecasts of monthly alfalfa hay prices in New Mexico are generated through the use of a linked model. The linked model

* This and the following article, while dealing with similar issues, were prepared independently of each other.

consists of a model estimated using annual data to forecast the price of alfalfa hay in May, the month of first harvest in New Mexico, and a system of equations estimated using monthly data to forecast subsequent monthly prices using the May price as a starting point.

The annual model is formulated as a four-equation, recursive, supply and demand model. This four-equation annual model is estimated using real prices. Real prices are calculated using the annual GNP implicit price deflator for the United States, with 1972 as base year. Because the annual model is recursive, it is estimated using ordinary least squares (OLS). The annual model was estimated using May 1960 through May 1982 data. The t-values for each estimated regression coefficient are in parentheses.

The first two equations in the model determine the annual alfalfa hay supply in New Mexico. Equation (1) estimates the New Mexico alfalfa hay acreage in the current year as a function of last year's alfalfa hay acreage.

Equation (1) is:

$$AA_t = 16{,}267.825 + 0.943AA_{t-1} \qquad (1)$$
$$(1.05) \qquad (12.51)$$
$$R^2 = 0.882, \qquad F = 156.41$$

where:

AA_t = New Mexico alfalfa hay acreage, year t.

Because alfalfa is a perennial, it was expected that the sign of AA_{t-1} would be positive and close to 1. This is the case and the coefficient for AA_{t-1} is significant at the $\alpha = 0.0001$ level. This simple autoregressive equation accounted for about 88 percent of the variation in annual alfalfa hay acreage in New Mexico.

Although producers undoubtedly consider factors other than last year's alfalfa acreage to determine this year's alfalfa acreage, reasonable alternatives proved to be statistically insignificant. Last year's cotton and grain sorghum prices were both tried with poor results, as was the alfalfa hay price in the previous year. Because alfalfa is a perennial crop, it is typically left in production for at least 5 years, once it is established. Such cultural practices assure the success of a simple autoregressive model, because much of what was in production last year will also be in production this year.

Equation (2) estimates annual alfalfa hay production as a function of current alfalfa hay acreage. The second equation is:

$$PA_t = -189{,}710.042 + 5.278AA_t \qquad (2)$$
$$(-2.75) \qquad (15.88)$$
$$R^2 = 0.920, \qquad F = 252.18$$

where:

PA_t = New Mexico alfalfa hay production in tons, year t.

The coefficient of alfalfa hay acreage (AA_t) was positive, as expected, and significant at the $\alpha = 0.0001$ level. The equation explained about 92 percent of the variation in annual New Mexico alfalfa hay production.

Both range conditions and a trend variable for technology were examined for possible use in equation (2). Neither variable entered was significant. A variable to account for weather influences upon alfalfa hay production was not included for two reasons. Because most alfalfa produced in New Mexico is irrigated, drought has little impact upon production. Further, even if weather or range conditions did enter as significant supply shifters, a user would have to forecast these weather variables for use in price forecasting.

Equation (3) in the annual model is a price-dependent demand equation for New Mexico alfalfa hay. The price-dependent formulation for alfalfa hay demand is appropriate because supply enters as a given from equation (2). In equation (3), the real May price for alfalfa in the current year is estimated as a function of current alfalfa hay production, the real April 1 price of a September corn futures contract, and a trend variable.

Equation (3) is:

$$RP_t = -1{,}596.52 + \underset{(4.16)}{0.116RCFP_t} \quad (-2.83)$$

$$- \underset{(-1.36)}{0.00001435PA_t} + \underset{(2.83)}{0.827YR_t} \qquad (3)$$

$$R^2 = 0.713, \qquad F = 16.59$$

where:

$RCFP_t$ = The April 1 price of a September corn futures contract in cents per bushel, Chicago, deflated by the GNP implicit price deflator, year t; and

YR_t = Year.

Because most feed ration ingredients are, to a large extent, substitutes, prices of these ingredients tend to move together. The April 1 price of a September corn futures contract was used to reflect the price of an important feed ration ingredient and the expected price of feedstuffs in general. The futures price was assumed to indicate market expectations for livestock feed inputs for the coming year. This coefficient was significant at the $\alpha = 0.0005$ level in equation (3).

Corn and soybean futures prices for various contract delivery dates were evaluated in equation (3), and the September corn futures contract was the most significant. A possible explanation for this is that the hay price formation process may be related to both the old and new corn crops. Some hay demand in early summer is for immediate consumption. This demand would be higher if old crop corn is in short supply. Hay prices can also be influenced by the expected feed availability for the coming winter, after the new corn crop is available. The September futures price for corn may work well because it is influenced by both old and new crop feed supplies. Livestock prices were also evaluated in equation (3) and found to have no significant relationship.

Year was included as a trend variable and was significant at the $\alpha = 0.01$ level in equation (3). This variable may be influenced by several other variables that have increased over this time period, such as cattle numbers.

The estimated coefficient for alfalfa hay production was negative, as expected, and was significant at the $\alpha = 0.19$ level. Although the alfalfa hay production variable in equation (3) appears to be statistically weak, exclusion of this variable from the equation resulted in poorer forecasts. Because this variable had the expected sign and its inclusion resulted in better forecasts, it was retained in the model.

Because real prices are used in the annual model, an equation to forecast the GNP implicit price deflator is needed to forecast with the annual model. This equation is:

$$GNPD_t = \underset{(-2.17)}{-664.092} + \underset{(38.40)}{1.062GNPD_{t-1}}$$

$$+ \underset{(2.15)}{0.337YR_t} \qquad (4)$$

$$R^2 = 0.998, \qquad F = 6{,}572.19$$

where:

$GNPD_t$ = Gross National Product implicit price deflator, 1972 = 100.

Although this is a simple model for forecasting the GNP implicit price deflator, it yielded good results.

Monthly Model

The relationships for forecasting the seasonal price pattern for alfalfa hay were estimated using OLS with data from January 1960 through December 1982. The monthly model consists of 11 price forecasting equations in which the current monthly price is estimated as a function of the previous monthly price. These relationships are estimated using real prices and can be used to track the price pattern throughout the season. The 11 monthly price forecasting relationships are:

$$\text{JUN} = \underset{(0.64)}{1.921} + \underset{(11.70)}{0.877\text{MAY}} \qquad R^2 = 0.872,\ F = 136.85 \tag{5}$$

$$\text{JUL} = \underset{(1.01)}{1.622} + \underset{(21.16)}{0.923\text{JUN}} \qquad R^2 = 0.957,\ F = 447.95 \tag{6}$$

$$\text{AUG} = \underset{(-0.48)}{-1.626} + \underset{(11.11)}{1.051\text{JUL}} \qquad R^2 = 0.860,\ F = 123.33 \tag{7}$$

$$\text{SEP} = \underset{(0.51)}{1.227} + \underset{(14.79)}{0.991\text{AUG}} \qquad R^2 = 0.916,\ F = 218.80 \tag{8}$$

$$\text{OCT} = \underset{(-0.09)}{-0.203} + \underset{(18.08)}{1.078\text{SEP}} \qquad R^2 = 0.942,\ F = 326.83 \tag{9}$$

$$\text{NOV} = \underset{(2.80)}{5.833} + \underset{(17.78)}{0.933\text{OCT}} \qquad R^2 = 0.940,\ F = 316.03 \tag{10}$$

$$\text{DEC} = \underset{(0.13)}{0.423} + \underset{(13.86)}{1.074\text{NOV}} \qquad R^2 = 0.906,\ F = 192.15 \tag{11}$$

$$\text{JAN} = \underset{(3.38)}{7.864} + \underset{(15.97)}{0.806\text{DEC}} \qquad R^2 = 0.927,\ F = 255.02 \tag{12}$$

$$\text{FEB} = \underset{(1.85)}{5.218} + \underset{(14.27)}{0.895\text{JAN}} \qquad R^2 = 0.911,\ F = 203.70 \tag{13}$$

$$\text{MAR} = \underset{(0.20)}{0.626} + \underset{(14.00)}{0.987\text{FEB}} \qquad R^2 = 0.907,\ F = 195.95 \tag{14}$$

$$\text{APR} = \underset{(1.42)}{5.217} + \underset{(10.84)}{0.873\text{MAR}} \qquad R^2 = 0.854,\ F = 117.40 \tag{15}$$

All estimated regression coefficients for the previous month's price are statistically significant at the $\alpha = 0.0001$ level. The lowest R^2 is 0.854 for the April equation (15). These estimated relationships indicate a stable price pattern for alfalfa hay throughout the season.

Linking the Models

Forecasts of average monthly alfalfa hay prices in New Mexico are generated in two stages. First, the annual model is used to forecast the real May price of alfalfa hay. This real price forecast could be converted to a nominal price forecast using a forecast of the GNP implicit price deflator from equation (4). All the information needed to forecast the May price is available by April 1. This provides price projections well in advance of the first alfalfa hay cutting. These price projections could be used by the industry in price negotiations for the coming year.

Second, the forecasted real May price from the annual model is used in equation (5) to forecast the real June price. Equations (5) through (15) are used iteratively to generate subsequent real monthly price forecasts through April of the following year. Again, the real monthly prices can be converted to nominal monthly prices by using equation (4). The use of the annual and monthly models in tandem provides both a forecast of the season starting price and subsequent monthly prices.

Even if the May price forecast from the annual model is fairly accurate, mechanical generation of subsequent monthly prices may err due to factors not included in the monthly models, such as a drought or insect infestations. If actual monthly alfalfa hay prices are incorporated into the monthly models as they become available, forecasting errors for the remainder of the season can be substantially reduced. Although the monthly models do not include such exogenous factors as drought, actual alfalfa hay prices incorporate these influences. Hence, use of actual alfalfa hay price information as it becomes available incorporates these exogenous factors into the price forecasts. This continued updating of monthly price forecasts keeps them on track and enhances the linked model's usefulness to buyers and sellers of alfalfa hay.

Error Analysis and Model Validation

Because an annual model and monthly models were combined to form the linked model, the root mean square error was calculated separately for the annual model, the system of monthly models and the linked model using January 1960 through December 1982 data. The root mean square error from the annual model (equations (1) through (4)) for the nominal May alfalfa hay price was \$3.20. With

TABLE 1. New Mexico Alfalfa Hay Prices per Ton: Actual, Forecasted and Residual, May 1983–October 1983.

		Using Four Equation Annual Model	
Month	Actual	Fore-casted	Residual
May 1983	92.00	93.36	−1.36
June 1983	87.00	86.15	0.85
July 1983	89.00	83.13	5.87
August 1983	87.00	83.75	3.25
September 1983	87.00	85.74	1.26
October 1983	90.00	91.98	−1.98

Source: Actual prices from U.S. Department of Agriculture, Statistical Reporting Service, Las Cruces, New Mexico.

a nominal mean May price of $44.21, the root mean square error for the annual model was 7.2 percent of the mean May price.

For the system of monthly models (equations (5) through (15)), which forecast the seasonal price pattern, the root mean square error was $5.58 and the mean monthly price for the period was $46.36. The root mean square error for the system of monthly price forecasting relationships was 12.0 percent of the mean monthly price.

The root mean square error for the linked model (equations (1) through (15)) was $5.30. With a mean monthly price of $46.36, the root mean square error for the linked model was 11.4 percent of the mean monthly price.

The performance of the linked model outside the sample was examined (Table 1). The root mean square error for May 1983 through October 1983 using the linked model was $2.97. This was 3.3 percent of the mean actual nominal price for these 6 months. Performance of the linked model outside of the sample compares favorably with the in-sample performance.

Conclusions

Two problems were identified in forecasting New Mexico alfalfa hay prices. The first was forecasting the initial starting price for each season. The second was forecasting the subsequent monthly seasonal price pattern. The technique used in this study was to develop separate models that would best forecast each of these aspects and then link the resulting models. This technique seemed to work well in this case. It is suggested that the technique might be applicable in forecasting other commodity prices where the initial season price establishes a level from which the subsequent seasonal price pattern begins.

The linked model developed in this study can serve as an independent source of information to help growers and users in the initial price discovery process each season. It also provides detailed monthly price information, which can be useful in making storage and forward contracting decisions.

References

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