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Tennessee Hay Supply and Demand Response to Prices and Other Factors

Jon Edwin Travis

University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Jon Edwin Travis entitled "Tennessee Hay Supply and Demand Response to Prices and Other Factors." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Roland Roberts, Major Professor

We have read this thesis and recommend its acceptance:

James Larson, Ernest Bazen

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor and
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Tennessee Hay Supply and Demand Response to Prices and Other Factors

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Jon Edwin Travis
December 2005

All I know about hay could be written in one sentence:
Cows like it.

-Mary F. Barber, 2005

Dedication

This thesis is dedicated to the memory of those family members involved in agriculture who have gone before me and is in honor of Buddy, Pat, Julie, and Jamie, whose constant and unconditional love helped to sustain me throughout this difficult task.

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First and foremost, I would like to recognize and thank an AWESOME God who provided me the gifts of strength, courage, patience, perseverance, and faith to complete this task. Without Him, I could do nothing, and would be nothing. Second, I would not have cleared this hurdle in life without the constant love and support of my wonderful parents and two beautiful sisters. Words cannot express my thankfulness.

My sincere and deep appreciation is expressed to my fellow graduate students, co-workers, and other friends. What little sanity I had prior to my time in Knoxville would, undoubtedly, have been lost without their companionship.

I would also like to thank Dr. Ernest Bazen and Dr. James Larson for their suggestions and willingness to serve on my faculty committee. Lastly, to the king of racquetball, Dr. Roland K. Roberts, thank you so much for your kindness, patience, and wisdom, as well as your belief in the potential of a young and restless farm boy from the rolling hills of Northwest Tennessee.

To everyone mentioned, you have my friendship forever.

Abstract

The hay industry in Tennessee closely resembles a perfectly competitive market. There are no substantial barriers to market entry and farmers can freely exit if they so choose. A large number of firms and consumers (livestock producers and equine operators) exist. Hay is a fairly homogeneous product; although hay varieties are not identical, in many livestock production situations they are close substitutes. Producers are price takers in the market.

Currently, more information is needed regarding Tennessee hay supply and price response. The objectives of this study were: 1) to determine the factors that influence Tennessee hay acreage and yield, 2) to quantify acreage and yield response to prices and other factors, 3) to determine the factors that influence Tennessee hay prices, and 4) to quantify hay price response to the quantity of hay and other factors. To accomplish these objectives, a recursive model of supply and price response was constructed. Acreage and yield elasticities and price flexibilities were estimated from the model's coefficients.

A ratio of lagged hay price to lagged wheat price, lagged hay acreage, and a time trend significantly impacted hay acreage. Hay yield responded to growing season rainfall, harvest season rainfall, lagged hay yield, and a time trend. Predetermined hay production, soybean meal price, per capita income, and a time trend significantly impacted Tennessee hay price.

Elasticities calculated from these results indicated that Tennessee hay producers respond weakly to own and substitute crop prices. This weak response may occur because many hay producers are also cattle producers that harvest their own hay in an effort to guarantee themselves a reliable supply of roughage to last their herds throughout the

winter months. They may be willing to give up potentially higher profits from a production alternative to avoid the risk of feed shortages for their cattle. This integration of hay and cattle production could explain why the acreage elasticity for lagged wheat price is small. Land in Middle and East Tennessee is less suited for row crop production as opposed to land in Western Tennessee. Fewer production substitutes for farmers in the middle and eastern parts of the state could explain a low acreage and yield elasticity for lagged own price. Row crop production may be a more suitable alternative for West Tennessee hay producers. The insignificance of lagged fescue seed price and ammonium nitrate price suggest that farmers do not respond to these input prices.

A weak responsiveness to prices by hay producers indicates that they may not attempt to purely maximize profit, but may be driven by other motivations, as well. Instead of profit maximizers, they may be utility maximizers who derive utility from a rural lifestyle, a psychological connection to the land, an aversion of risk with regard to a stable roughage source, and/or other objectives.

With the exception of income, calculated flexibilities suggested that price responds weakly to economic factors. A strong response of hay price to income was reasonable to expect; an increase in real per capita income would result in more purchasing power for a typical household. As purchasing power becomes greater, one could expect that beef consumption would also increase since beef is considered a normal good. This increased beef consumption would lead to an increased demand for roughage and grain feed. A weak response of hay price to predetermined hay production can also be explained by many hay producers performing a dual role as livestock producers. These farmers may be able to produce hay at a lower cost than market price, or they may be willing to forgo the potential cost savings of buying hay from an outside source to avoid feed shortages for their cattle. Lastly, hay price seemed to be relatively unresponsive to prices of other feed options.

The study is an aid to those interested in hay producer and consumer behavior and can be used to formulate future forage and other agricultural-related policies.

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Part 1: Introduction

The hay industry in Tennessee closely resembles a perfectly competitive market. There are no substantial barriers to market entry and farmers can freely exit if they so choose. A large number of firms and consumers (livestock producers and equine operators) exist. Hay is a fairly homogeneous product; although hay varieties are not identical, in many livestock production situations they are close substitutes. Producers are price takers in the market (Shumway).

In 2002, approximately 47,000 operations within the state were involved in some type of forage production (U.S. Department of Agriculture, 2004). During this time, Tennessee farmers produced approximately 4,200,000 tons of hay (U.S. Department of Agriculture, 2005). In 2002 alone, approximately 50,000 beef and dairy operations, as well as approximately 24,000 equine operations, called Tennessee their home. These farms housed approximately 2,234,000 head of cattle and calves and approximately 149,000 head of equine (U.S. Department of Agriculture, 2004). Hay is an input used in the beef, dairy, and equine industries. The demand for hay is derived from output demand of these industries (Nicholson).

Despite the lack of a national or state central market for hay, buyers and sellers seem to be aware of the market-clearing price for their area at any given moment. Word of mouth, a hay directory website, and the *Farm Facts* bulletin are among the primary outlets of price discovery for Tennessee farmers (Tennessee Agricultural Statistics Service; Rawls). The Tennessee Hay Directory website does not display prices (Tennessee Farm Bureau Federation). It does, however, provide relevant information such as producer contact information and quantity available for sale to assist the buyer in finding the type of hay he/she is seeking. Prospective buyers can then contact the producer and negotiate a price. These negotiations help the buyer and seller better grasp the market price. *Farm Facts* is a semimonthly publication that provides various agricultural data to the public; alfalfa and other hay prices for previous years are made available once a year (Tennessee Agricultural Statistics Service; Rawls).

Farmers produce various types of hay within the state. These types include legume, grass, and mixtures of both (Cross). Tall fescue, a cool-season perennial, is the most popular grass harvested for hay in Tennessee but alfalfa usually brings the highest price on the market (Bates; Cross). Regardless, during the year of 2003, alfalfa only accounted for approximately 3% of total hay produced within the state and approximately 8% over the 37-year period of 1967-2003 (U.S. Department of Agriculture, 2005). Therefore, when examining hay supply and demand, it seems fitting to study the market in a comprehensive manner.

More information is needed in regard to the intricacies of the hay market in Tennessee. This study will determine elasticities and flexibilities for the relevant variables that affect hay supply and market price, respectively, in Tennessee. The objectives of this study were: 1) to determine the factors that influence Tennessee hay acreage and yield, 2) to quantify acreage and yield response to prices and other factors, 3) to determine the factors that influence Tennessee hay prices, and 4) to quantify hay price response to the quantity of hay and other factors. To accomplish these objectives, a model of supply and price response was constructed. This model consists of three equations which represent hay acreage, hay yield, and hay price. If error correlation cannot be found among these equations, a recursive model would be appropriate. Kennedy suggests that OLS estimation is consistent when no error correlation exists among equations.

However, indication of autocorrelation in any one of the equations would result in an alternative estimation method for that equation. On the other hand, if evidence is found to suggest a correlation of errors among the equations, a simultaneous model would be appropriate. A three-stage least squares approach is acceptable when estimating simultaneous models that would be recursive without cross-equation correlation of errors (Greene). Elasticities and flexibilities are then calculated from the coefficients of the three equations. When examined in a comprehensive manner, fulfilling these objectives will improve hay producers' and consumers' knowledge of supply and price response for this important component of the Tennessee agriculture sector.

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Part 2: Tennessee Hay Supply Response to Prices and Other Factors

Introduction

Understanding the factors that influence hay supply in Tennessee is important because of the impact hay production has on Tennessee agriculture and its economy. The production of hay is an important aspect of Tennessee agriculture (Cross). Hay, a perennial crop, is considered one of the leading agricultural commodities in the state. During 2002 and 2003, this crop ranked eleventh and tenth, respectively, in cash receipts among the state's leading agricultural products even though its production only accounted for 2.0% ($41,186,000) and 1.8% ($41,324,000) of those receipts. In 2003, Tennessee also ranked fourth nationally in other hay production (all hays excluding alfalfa) at 4,600,000 tons and thirty-second in alfalfa production at 126,000 tons (U.S. Department of Agriculture, May 16, 2005).

Currently, more information is needed regarding hay supply response to prices because of its economic importance to hay producers and the Tennessee livestock industry, including equine, beef, and dairy producers. Information about hay supply response will improve understanding of the supply-side complexities of the hay market. Identifying the factors that influence hay supply and understanding the extent of their impacts could assist lawmakers in formulating agricultural policy that would better serve hay and livestock-related operations. Quantifying acreage and yield response to prices and other factors could assist hay producers to better anticipate the market for their product and livestock producers to anticipate the supply of a major input in their production activities.

Extensive research is available regarding the determinants of perennial crop supply, but research on hay supply response is limited. Perennial supply response was first modeled in 1956 for apples by French (Elnagheeb and Florkowski). In 1971, French and Matthews developed a multi-equation structural model to represent perennial crop supply response that was illustrated using asparagus data. They incorporated plantings and removals into their model. No supply elasticities were calculated. Shumway created supply response equations for six Texas field crops in 1983, hay being one of these. Equations were estimated by seemingly unrelated regression. Shumway then calculated elasticities from his parameter estimates. In 1984, Blake and Clevenger developed an alfalfa hay price forecasting model that included estimation of an alfalfa acreage equation. A 1993 study by Elnagheeb and Florkowski compared two methods used to estimate non-bearing pecan tree numbers: one whose methodology was based on the previously mentioned French and Matthews study and another that utilized changes in production to estimate non-bearing tree numbers. Both methods assumed that new plantings were a function of lagged pecan prices and input costs. They discovered that the French and Matthews method was more practical and accurate in its estimation of new plantings. However, no supply elasticities were formulated in their study.

Knapp created a dynamic equilibrium model in 1987 under rational expectation assumptions that represented the California alfalfa crop. In 1988, Konyar and Knapp created an acreage response equation for California alfalfa but did not model its yield. Then in 1991, Knapp and Konyar examined California alfalfa production in greater depth than before by creating equations to specifically represent new plantings and removals. They used the Kalman filter approach and examined their model under two assumptions: naive price expectations and quasi-rational expectations. Elasticities were calculated in both studies (Konyar and Knapp; Knapp and Konyar). Other studies on perennial crop supply response include French and Bressler, Bateman, Behrman, and Baritelle and Price.

Although variables examined in this study are relevant to the decision to plant hay and/or remove it, the estimation of Tennessee hay supply response to prices and other factors is not dependent upon estimating plantings and removals. This is due to plantings and removals basically being functions of own and production alternative profit expectations. A supply response model using the partial adjustment framework would seem appropriate for the construction of a perennial supply response model. The partial adjustment framework accounts for current plantings and removals through current profit expectations. It also implicitly accounts for plantings and removals from previous years through the inclusion of a lagged dependent variable.

The first objective of this study was to determine the factors that influence Tennessee hay acreage and yield. The second objective was to quantify acreage and yield response to prices and other factors. When examined comprehensively, accomplishing these objectives will improve understanding of supply response for this important component of the Tennessee agriculture sector.

Model Specification

The Tennessee hay industry bears a strong resemblance to a perfectly competitive market. No substantial barriers to market entry exist and farmers can freely exit at will. A large number of firms and consumers, mainly livestock producers, exist. Hay is a fairly homogeneous product; although hay varieties are not identical, in many livestock production situations they are close substitutes.

Given that the hay market in Tennessee is close to being perfectly competitive, hay farmers are assumed to be price takers in the market. Ostensibly, this means that hay farmers can sell all the hay they produce at the prevailing price. Shumway notes that hay producers are undoubtedly price takers in their market. The theory of the firm suggests that farmers will choose the quantities of inputs and outputs so that profits are maximized where the marginal cost of production equals the price they receive for their product (Nicholson). The following Tennessee supply-response model was specified for harvested hay based on the theory of the firm in a competitive market. This model was used to accomplish the objectives.

Because hay production equals acreage multiplied by yield per acre, the factors that influence supply influence it through their effects on acreage and yield. The following equations were specified for annual hay acreage, yield, and production in Tennessee:

$$(1) \qquad ACRES_t = \beta_{10} + \beta_{11}\frac{HAYP_{t-1}}{WHEATP_{t-1}} + \beta_{12}SEEDP_{t-1} + \beta_{13}ACRES_{t-1} + \beta_{14}TIME_t + e_{1t},$$

$$(2) \qquad \begin{aligned} YIELD_t &= \beta_{20} + \beta_{21}HAYP_{t-1} + \beta_{22}FERTP_t + \beta_{23}GROWING_t + \beta_{24}HARVEST_t \\ &+ \beta_{25}YIELD_{t-1} + \beta_{26}TIME_t + e_{2t} \end{aligned},$$

$$(3) \qquad HPROD_t = A_t \times Y_t,$$

where *ACRES* is total hay acreage harvested (1,000 acres); *YIELD* is state average hay yield (tons/acre); *HPROD* is total hay production (1,000 tons); *HAYP* is season-average hay price received by Tennessee farmers ($/ton); *WHEATP* is season-average wheat price received by Tennessee farmers ($/bushel); *SEEDP* is U.S.-average tall fescue seed price in April ($/cwt.); *TIME* is time trend with 1967 = 1, 1968 = 2,…,2003 = 37; *FERTP* is

March or April price for ammonium nitrate fertilizer in Tennessee/East South Central Region ($/ton); *GROWING* is county-average cumulative rainfall during the growing season of October through November in the previous year and February through April in the current year for the top ten hay producing counties in Tennessee (inches); *HARVEST* is county-average cumulative rainfall during the harvest season of May through September in the current year for the top ten hay producing counties in Tennessee (inches); *e* is a random error; β_{ij} ($i = 1,2; j = 0...6$) are parameters to be estimated; *i* represents the equation number; *j* represents the coefficient in equation *i*; and *t* is a subscript for the current year. All prices were deflated by the index (2003 = 1.0) of farm production items, interest, taxes, and wage rates (U.S. Department of Agriculture, 1967-2004A). This allowed the model to account for the prices of other production inputs not directly represented in Equations (1) and (2) and convert prices into 2003 real dollars.

Output price expectations were represented by naive expectations because the selling prices of hay and wheat at harvest time are not known when hay acreage is planted or removed from production. The coefficients for $HAYP_{t-1}/WHEATP_{t-1}$ in Equation (1) (β_{11}) and $HAYP_{t-1}$ in Equation (2) (β_{21}) were expected to be positive. The ratio of $HAYP_{t-1}$ and $WHEATP_{t-1}$ was used to reduce multicollinearity in Equation (1). French and Matthews recommended the inclusion of a substitute good price into their asparagus supply response model but were unable to do so because no predominant production alternative could be identified for asparagus farmers. The price of wheat ($WHEATP_{t-1}$) was included to represent the expected price of an acreage substitute in production. Data from the 2002 Census of Agriculture indicate that most hay is produced in the middle and eastern portions of the state, where land geography is more conducive to erosion (U.S. Department of Agriculture, 2004). The use of a winter cover crop such as wheat lessens the effects of soil erosion (Larson et al.). Thus, wheat would appear to adequately represent an expected substitute crop price. French and Matthews state that current expectations of profit should be included when perceived to be important to yield response. Profit expectations were represented by $HAYP_{t-1}$ and $SEEDP_{t-1}$ in Equation (1) and $HAYP_{t-1}$ and $FERTP_t$ in Equation (2).

Lagged tall fescue seed price ($SEEDP_{t-1}$) and ammonium nitrate price ($FERTP_t$) represent input costs of hay production. Tall fescue, a cool-season perennial, is the most popular grass harvested for hay in Tennessee (Bates, January 2005). Its seed price was lagged one year to account for the cost of a production input at planting time, which was assumed to occur in the late summer to early fall before harvest. Numerous farmers prefer seeding fescue in the late summer and early fall as opposed to spring in the year of harvest; doing this in the late summer to early fall allows for planting in more appropriate weather and also divides work in a more even way over the year (Lacefield et al.). Ammonium nitrate is an input that affects yield (Bates, 1994). Most farmers apply this fertilizer in March, prior to harvest (Bates, June 2005). As suggested by economic theory, the signs of β_{12} and β_{22} should be negative (Nicholson). The incorporation of these input prices into the acreage and yield equations allowed the effects of input prices on acreage and yield to be estimated. Konyar and Knapp included input prices in their acreage response model by deflating own price and production alternative price by the "USDA's cost of crop production index." French and Matthews represented input prices by deflating own price by the farm wage rate index.

Growing season rainfall (*$GROWING_t$*) is represented by 10-county averages of cumulative precipitation during October and November in year *t-1* and February-April in year *t*. Upon examination of a grain and forage crop guide by Bitzer et al., precipitation during the period of May-September was deemed appropriate to represent harvest season rainfall (*$HARVEST_t$*). The majority of growth occurs in cool-season grasses during the months mentioned above that represent the hay growing season (Bates, 1999; Lacefield, Henning, and Phillips). When exposed to rain during the curing process, cut hay experiences nutrient and dry matter loss (Bates, 1994; Collins; Scarbrough et al.; Smith and Brown; Sundberg and Thylén). However, harvest season rainfall between cuttings promotes growth. This positive effect of rainfall during the harvest season is expected to outweigh the negative effect on yield during the curing process. Therefore, the signs of coefficients β_{23} and β_{24} were both expected to be positive. In previous studies, Bateman successfully incorporated weather variables into a 1965 study on Ghanaian cocoa supply response while Knapp and Konyar and French and Matthews assumed the effects of weather on yield were a random disturbance included in the error term. Elnagheeb and Florkowski also attempted to include weather variables in their pecan supply response model but eventually excluded them due to their statistical insignificance.

Lagged hay acreage ($ACRES_{t-1}$) in Equation (1) and lagged hay yield ($YIELD_{t-1}$) in Equation (2) were included under the hypothesis of partial adjustment (Nerlove; Kennedy; Ramanathan). Ramanathan states that a lagged dependent variable accounts for "increasing costs associated with rapid change, or noting technological, institutional or psychological inertia." Inclusion of lagged dependent variables in perennial supply response models incorporates the impacts of independent variables in years preceding *t-1*.

The coefficients for $ACRES_{t-1}$ and $YIELD_{t-1}$ (β_{13} and β_{25}) were expected to be between zero and one. Konyar and Knapp initially estimated acreage response as a function of prices with one to five-year lags. Finding that this initial model suffered from extreme multicollinearity, they resorted to a partial adjustment framework with naive price expectations and found all hypothesized variables significant at the 5% level.

A time trend ($TIME_t$) was included in Equations (1) and (2). Cross illustrated that Tennessee hay acreage had been trending upward from 1980-1998. Further analysis has shown that acreage continued to increase from 1998-2003. Cross attributed this increased hay acreage to an increased number of farmers who were searching for production alternatives to annual grain crops and tobacco production as they tried to incorporate conservation-oriented crops, such as hay, into their operations. These conservation activities were promoted by Congress in various farm bills, the latest being Title II, Subtitle A of the Farm Security and Rural Investment Act of 2002 (Cross; U.S. Congress, House of Representatives and Senate). A time trend was included in Equation (1) to account for increased hay acreage in response to the increased emphasis on conservation-oriented crops. The time trend was included in Equation (2) to account for improvements in yield-increasing technology over time. State acreage and yield data for the 1966-2003 period appeared to increase as illustrated in figures 1 and 2 of the Appendix.

Equations (1) and (2) in Part 2 and Equation (3) in Part 3 were originally estimated with Ordinary Least Squares (OLS). Error terms were then tested for correlation across equations. To do this, Bartlett proposed testing the correlation matrix against the identity matrix with a chi-squared statistic. Correlations of residuals across equations would imply simultaneity; a three-stage least squares approach would then be deemed appropriate (Greene). However, if error terms were shown to be uncorrelated, the model would be recursive and single-equation regression methods could be used to estimate each equation in the model. A recursive model is characterized by its endogenous variables operating in only one direction. Equations in recursive models are arranged in such a manner that poses each equation as a function of predetermined and/or exogenous variables (Kennedy).

If the model was recursive and an equation exhibited no evidence of autocorrelation, OLS could be used. The Durbin-H statistic was used to test for autocorrelation in Equations (1) and (2). Giving no attention to autocorrelation when present in a regression leads to inconsistent and biased estimates that are inefficient (Ramanathan). If autocorrelation were indicated, the equation would be re-estimated with a first-order autoregressive term (ρ) using Maximum Likelihood (ML).

Elasticites were calculated from the results of Equations (1) and (2). Short-run elasticities were calculated as follows:

$$e_{Y_i, X_{ij}} = \frac{\partial Y_i}{\partial X_{ij}} \times \frac{\overline{X}_{ij}}{\overline{Y}_i},$$

where Y represents the dependent variable in equation i; X represents independent variable j in equation i; $\overline{X}_i$ represents the mean of independent variable j in equation i; and $\overline{Y}_i$ represents the dependent variable mean in equation i. Long-run elasticities were calculated according to Nerlove as:

$$e_{LY_i, X_{ij}} = \left(\frac{\partial Y_i}{\partial X_{ij}} \times \frac{\overline{X}_{ij}}{\overline{Y}_i} \right) \Big/ \left(1 - \beta_{i,j=3 \text{ and } 5}\right),$$

where β represents the coefficient of lagged dependent variable j in equation i.

Data

Equations (1) and (2) were estimated from annual time series data for the 1967-2003 period. Data for hay acreage, price, and yield were collected from U.S. Department of Agriculture (March 4, 2005). Wheat price is reflective of the Tennessee marketing year average. This price was taken from U.S. Department of Agriculture (March 4, 2005). The U.S. average retail price for tall fescue seed was gathered from U.S. Department of Agriculture (1967-2004B). Seed prices for 1968-2003 were for April. Seed prices before 1968 were U.S. February-May season average prices. The ammonium nitrate price was taken from U.S. Department of Agriculture (1967-2004A). Price data were reported for April in 1967-1976 and March in 1977-1985. April prices were again available for 1986-2003 (U.S. Department of Agriculture, 1967-2004A; Williams). Tennessee ammonium nitrate prices were available during 1967-1976; only East South Central Region prices were available thereafter. The East South Central Region consists of Alabama, Kentucky, Louisiana, Mississippi, and Tennessee (U.S. Department of Agriculture, 1967-2004A).

Growing and harvest season rainfall for the top ten counties in hay acreage[1] were collected from the National Climatic Data Center (U.S. Department of Commerce). Analysis of county acreage data for the 1990-2003 period showed that the top 10 hay counties in Tennessee were Bedford, Giles, Greene, Lincoln, Maury, Robertson, Sumner, Washington, Williamson, and Wilson (U.S. Department of Agriculture, March 4, 2005).

One complication that arose was the lack of rainfall data in certain years for some counties. This lack of county data was remedied by substituting rainfall from a

[1] Hay acreage in Tennessee counties is reported as alfalfa acreage and other hay acreage. Alfalfa acreage represents a small percentage of the entire hay acreage in Tennessee; therefore, leading counties in other hay acreage were used as the top 10 hay producing counties.

neighboring county for the missing observations. Counties that visually appeared to share the longest border were given priority as substitutes for missing observations. Greene County and Washington County data, Giles County and Lincoln County data, and Maury and Williamson County data were substituted for each other for their missing observations. However, in the occasional case when both Greene County and Washington County data were not available, Hawkins County data were used. Also, Lawrence County data were used during the occasional months when both Giles County and Lincoln County data were missing. Lastly, Rutherford County data were used in place of unavailable Bedford County observations.

Results

The Bartlett test for cross-equation correlation of errors produced a chi-squared value of 3.51, compared to the critical value of 7.81 (three degrees of freedom at the 5% significance level). The null hypothesis of no cross-equation correlation of errors could not be rejected. Therefore, the acreage and yield equations were assumed to be the first two equations in a three equation recursive model; the third equation being the hay price equation that will be discussed in Part 3.

The computed Durbin-H statistics for the acreage and yield equations were -2.28 and -1.54, respectively. When compared to the Durbin's H critical value of -1.96, the null hypotheses of no autocorrelation was rejected for Equation (1) but could not be rejected for Equation (2). Equation (1) was re-estimated with the ML method to correct for autocorrelation (SAS Institute Inc.). Upon re-estimation, ρ was significantly different from zero at the 5% level.

Results of the ML acreage equation are listed in table 1. All of the significant coefficients possess signs that correspond with economic theory. The coefficient for $SEEDP_{t-1}$ had a positive sign, contrary to theory, but was not significantly different from zero. The total R^2 was 0.97.

The OLS estimation of Equation (2) produced four variables that were significantly different from zero, and R^2 and adjusted R^2 values of 0.84 and 0.81, respectively. Collinearity diagnostics indicated evidence of multicollinearity between the intercept (variance proportion of 0.99) and $HAYP_{t-1}$ (variance proportion of 0.51) at a condition index of approximately 55; thus, the standard error of the coefficient for $HAYP_{t-1}$ may have been seriously degraded by multicollinearity and the failure to reject the null hypothesis that this coefficient equals zero may be misleading. Multicollinearity was also shown to exist between $TIME_t$ and $YIELD_{t-1}$ with variance proportions of 0.85 and 0.69, respectively, at a condition index of approximately 35. Nevertheless, the coefficients for these variables were significantly different from zero, suggesting that multicollinearity was not a serious problem. Table 2 displays OLS results for Equation (2). All coefficient signs agreed with *a priori* expectations. Significant variables were $GROWING_t$, $HARVEST_t$, $YIELD_{t-1}$, and $TIME_t$.

All short-run elasticities presented in tables 3 and 4 are inelastic. $ACRES_t$ responded to significant variables $HAYP_{t-1}$ and $WHEATP_{t-1}$ with elasticities of 0.08 and -0.08, respectively, while $YIELD_t$ responded to significant variables $GROWING_t$ and $HARVEST_t$ with elasticities of 0.12 and 0.14, respectively. These short-run elasticities suggest that Tennessee hay producers are fairly unresponsive to changes in prices in adjusting hay acreage and yield.

Tables 3 and 4 also display long-run elasticities. All long-run elasticities are larger than short-run elasticities as suggested by significant lagged dependent variables. This finding supports the idea that Tennessee hay farmers are more responsive over a longer time period to own and competing crop prices. However, one should note that long-run responses of hay acreage and yield are still inelastic, suggesting that hay farmers do not respond strongly to prices when making their production decisions. In the long-run, $ACRES_t$ responded to significant variables $HAYP_{t-1}$ and $WHEATP_{t-1}$ with elasticities of 0.16 and -0.16, respectively, while $YIELD_t$ responded to significant variables $GROWING_t$ and $HARVEST_t$ with respective elasticities of 0.19 and 0.22.

Conclusion

A supply response model for Tennessee hay acreage and yield and the calculation of its corresponding elasticities were presented. Acreage and yield equations were created to reflect the dynamics of hay production in a partial adjustment framework. The major barriers to completing this task were calculating rainfall variables and addressing the problems of multicollinearity and autocorrelation.

A ratio of lagged hay price to lagged wheat price, lagged own acreage, and a time trend significantly impacted hay acreage. A first-order autoregressive term was included to adjust for autocorrelation. Hay yield only responded to growing season rainfall, harvest season rainfall, lagged hay yield, and a time trend. Autocorrelation was not indicated in the yield equation.

Hay acreage response proved to be inelastic in both the short and long runs with respect to changes in all price variables. Yield was not responsive to prices; however, this conclusion is uncertain for $HAYP_{t-1}$ because of multicollinearity. These results indicate that hay producers in Tennessee respond weakly to own and substitute crop prices. This weak response may happen because many hay producers are also cattle producers that harvest their own hay in an effort to guarantee themselves a reliable supply of roughage to last their herds throughout the winter months. They may be willing to give up potentially higher profits from a production alternative to avert feed shortages for their cattle; Konyar and Knapp came to a similar conclusion in regard to a reliable roughage supply. This finding may explain why the elasticity for $WHEATP_t$ is small. Also, according to the 2002 Census of Agriculture and illustrated in figure 3, a substantial number of hay producers reside in Middle and East Tennessee (U.S. Department of Agriculture, 2004). Land in this area of the state is less suited for row crop production as opposed to land in the western part of the state. Fewer production substitutes for Middle and East Tennessee farmers could explain a low elasticity for $HAYP_{t-1}$. Row crop production may be a more suitable alternative for West Tennessee hay producers. The insignificance of $SEEDP_{t-1}$ and $FERTP_t$ suggest that farmers are not responsive to seed and nitrogen prices.

This study operated under the assumption that hay producers were profit maximizers. A weak responsiveness to prices by these farmers indicates that they may not attempt to purely maximize profit, but may be driven by other motivations, which enter into their objectives as utility maximizers. Maximization of utility may be derived from a rural lifestyle, a psychological connection to the land, and/or an aversion of risk with regard to a stable source of roughage.

If the appropriate data became available in the future, variety-specific hay acreage response equations could be created with the purpose of comparing elasticities among the various varieties of forage crops cut for hay. This completed study and any further extensions of it will aid lawmakers in formulating future forage and agricultural-related policies.

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Appendix

Table 1. Maximum Likelihood Estimates of Acreage Equation Adjusted for First-Order Autocorrelation

Variable[a]	Coefficient	T-Value
Intercept	365.13***	3.12
$HAYP_{t-1}/WHEATP_{t-1}$	7.42***	3.11
$SEEDP_{t-1}$	0.06	0.14
$ACRES_{t-1}$	0.48***	3.53
$TIME_t$	14.52***	3.96
AR1	0.42**	2.16

[a] HAYP = Tennessee hay price; WHEATP = Tennessee wheat price; SEEDP = U.S. tall fescue seed price; ACRES = Tennessee harvested hay acreage; TIME = time trend; and AR1 = first-order autoregressive term.
*** and ** indicate significance at the 1% level and 5% level, respectively.

Table 2. Ordinary Least Squares Estimates of Yield Equation

Variable[a]	Coefficient	T-Value
Intercept	0.17	0.39
$HAYP_{t-1}$	0.003	1.11
$FERTP_t$	-0.0005	-0.87
$GROWING_t$	0.01*	1.68
$HARVEST_t$	0.01*	1.78
$YIELD_{t-1}$	0.38**	2.43
$TIME_t$	0.02***	2.72

[a] HAYP = Tennessee hay price; FERTP = Tennessee/East South Central Region ammonium nitrate price; GROWING = growing season rainfall; HARVEST = harvest season rainfall; and TIME = time trend.
***, **, and * indicate significance at the 1% level, 5% level, and 10% level, respectively.

Table 3. Acreage Elasticities and Related Calculations

Variable[a]	Short-Run Elasticity	Long –Run Elasticity	Sample Mean[b]
$HAYP_{t-1}$	0.08	0.16	83.89 ($/ton)[c]
$WHEATP_{t-1}$	-0.08	-0.16	5.02 ($/bushel)
$SEEDP_{t-1}$	0.004	0.009	106.52 ($/cwt.)

[a] HAYP = Tennessee hay price; WHEATP = Tennessee wheat price; and SEEDP = U.S. tall fescue seed price.
[b] Acreage sample mean is 1483.24 (1,000 acres).
[c] Sample mean units are specified in parenthesis.

Table 4. Yield Elasticities and Related Calculations

Variable[a]	Short-Run Elasticity	Long –Run Elasticity	Sample Mean[b]
$HAYP_{t-1}$	0.13	0.20	83.89 ($/ton)[c]
$FERTP_t$	-0.07	-0.11	262.42 ($/ton)
$GROWING_t$	0.12	0.19	21.60 (Inches)
$HARVEST_t$	0.14	0.22	21.74 (Inches)

[a] HAYP = Tennessee hay price; FERTP = Tennessee/East South Central Region ammonium nitrate price; GROWING = growing season rainfall; HARVEST = harvest season rainfall; and TIME = time trend.
[b] Yield sample mean is 1.81 (tons).
[c] Sample mean units are specified in parenthesis.

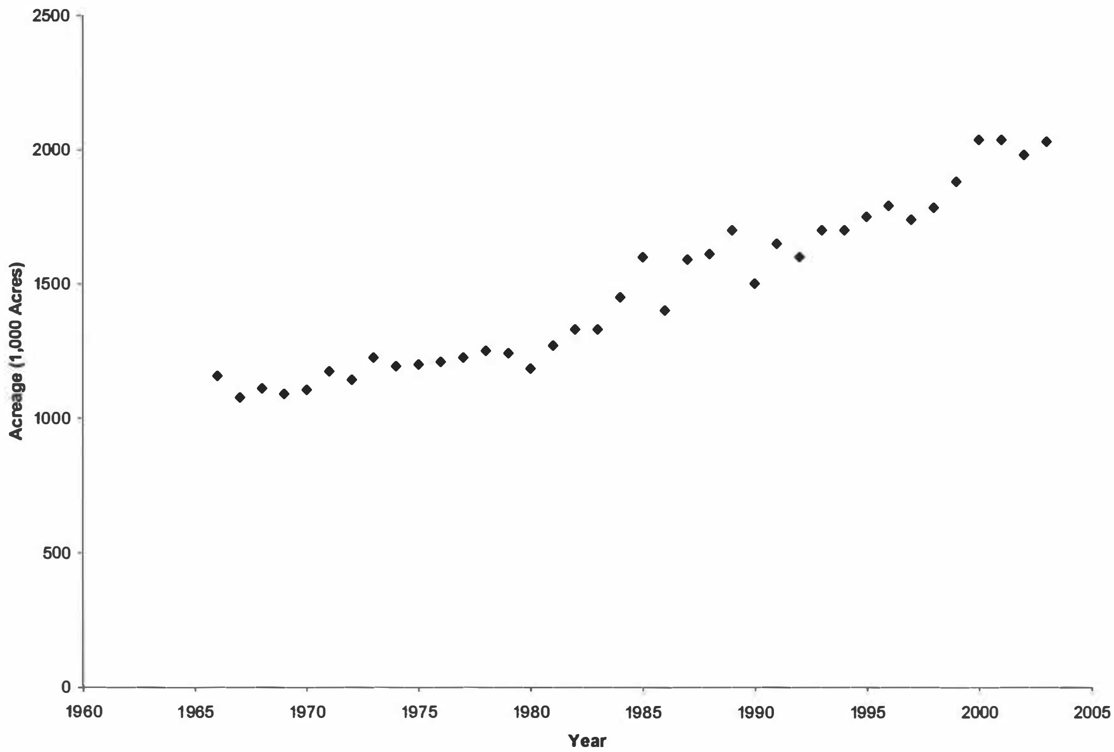

Figure 1. Annual hay acreage for the state of Tennessee, 1966-2003
Source: U.S. Department of Agriculture (March 4, 2005)

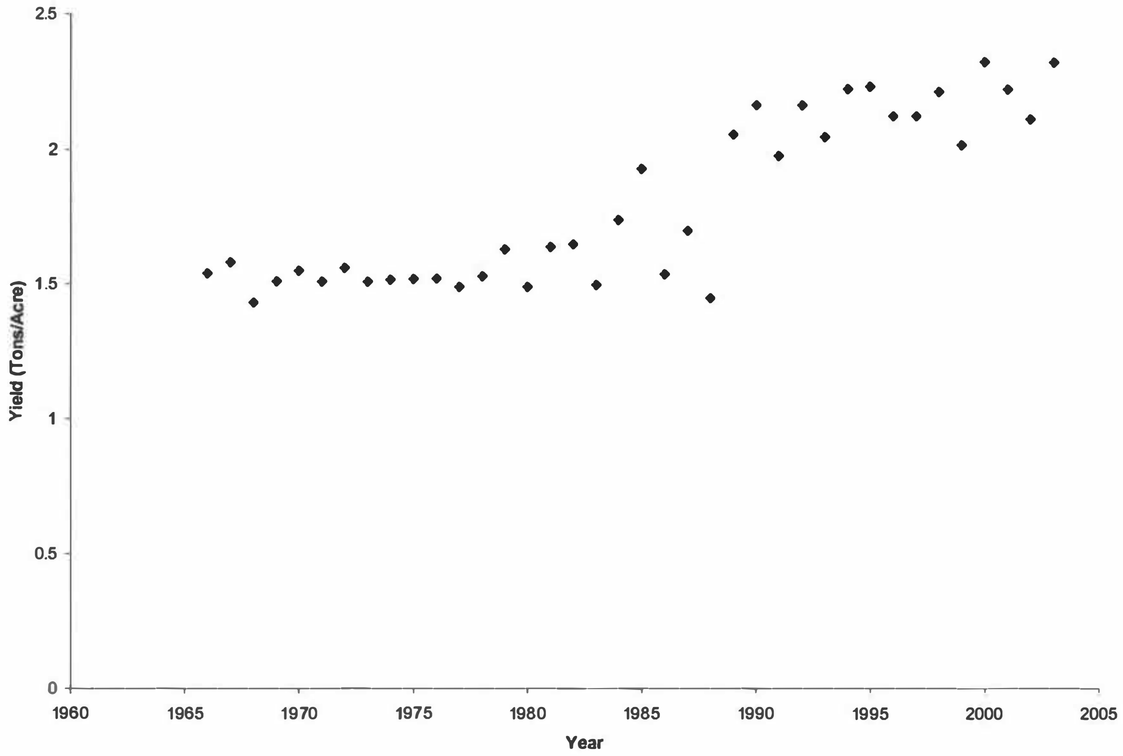

Figure 2. Annual hay yield for the state of Tennessee, 1966-2003
Source: U.S. Department of Agriculture (March 4, 2005)

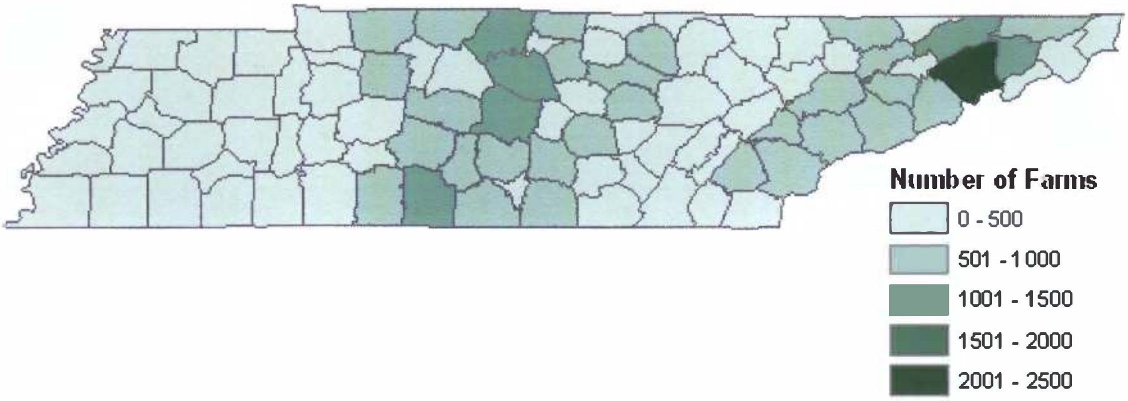

Figure 3. Tennessee forage production distribution by number of farms, 2002
Source: U.S. Department of Agriculture (2004)

Part 3: Tennessee Hay Price Determination

Introduction

The hay crop is important to the state of Tennessee, accounting for cash receipts totaling $41,186,000 in 2002 and $41,324,000 in 2003 (Cross; U.S. Department of Agriculture, May 16, 2005). Hay, a perennial crop, is considered one of the state's largest agricultural commodities. In 2003, Tennessee ranked fourth nationally in other hay production (all hays excluding alfalfa) at 4,600,000 tons and thirty-second in alfalfa production at 126,000 tons (U.S. Department of Agriculture, May 16, 2005).

According to the 2004 Tennessee Equine Survey, the state housed 210,000 horses; the 2002 Census of Agriculture ranked Tennessee second nationwide in equine numbers (U.S. Department of Agriculture, May 16, 2005). The January 1, 2004 inventory showed that Tennessee cattle and calves (dairy and beef) numbered 2,210,000 head placing the state 14th in the United States (U.S. Department of Agriculture, May 16, 2005). Given that hay is a production input for horses, beef cattle and calves, and dairy cattle and calves, the evident demand for this product more than justifies its research.

To investigate hay demand, one must understand the physical characteristics of its market. These markets are usually localized because of the product's weight and bulky physical characteristics; a national hay market is non-existent (Cross). Currently, a standard quality grading system does not exist. Scarcity of information available to the public suggests that research on the factors that influence hay prices will provide hay and livestock producers with valuable information for making business decisions.

Despite the lack of a national or state central market, buyers and sellers seem to be aware of the market-clearing price for their community at any given moment. Word of mouth, a hay directory website, and the *Farm Facts* bulletin are among the primary outlets of price discovery for Tennessee farmers (Rawls). The Tennessee Hay Directory website does not display prices (Tennessee Farm Bureau Federation). It does, however, provide relevant information such as producer contact information and quantity available for sale to assist the buyer in finding the type of hay he/she is seeking. Prospective buyers can then contact the producer and negotiate a price. These negotiations help the buyer and seller better grasp the market price. *Farm Facts* is a semimonthly publication that provides various agricultural data to the public; prices for alfalfa and other hays are made available once a year (Tennessee Agricultural Statistics Service; Rawls).

A small amount of research exists on hay demand-related topics. Grisley, Stefanou, and Dickerson studied the effects of certain factors on successful bids at a hay auction in Pennsylvania. Their study focused on the impacts of the specific market for which a load of hay was purchased, hay type, and buyer characteristics toward winning bid prices. Myer and Yanagida estimated alfalfa hay price forecasts by combining annual econometric forecasts with quarterly ARIMA forecasts. To forecast alfalfa hay price, they presented an inverse demand equation. Blake and Clevenger developed an alfalfa hay price forecasting model for the first cutting of the season by linking an annual model that predicted the beginning May hay price to a monthly model. Another alfalfa price forecasting model was created by Konyar and Knapp as part of a broader study on the California alfalfa market. Hopper, Peterson, and Burton represented alfalfa price as a function of quality and physical traits.

No previous research has been conducted to determine the influence of demand factors on hay prices in Tennessee. The objectives of this study were to determine

Tennessee hay price response to various economic factors and to determine corresponding price flexibilities.

Model Specification

The Tennessee hay industry strongly resembles a perfectly competitive market. There are no substantial barriers to market entry and firms (hay producers) can freely exit at will. A large number of firms and consumers, mainly livestock producers, exist. Hay is a reasonably homogeneous product; although hay varieties are not identical, in many livestock production situations they are close substitutes.

The study requires specification of an inverse demand function and the estimation of its coefficients. An inverse demand equation is characterized by price being the dependent variable. This type of equation "measures the price at which a given quantity will be demanded (Varian)." An inverse demand equation is appropriate because the quantity is assumed known from Equation (3) of Part 2; Blake and Clevenger and Myer and Yanagida state that the use of an inverse demand equation is apt in situations where supply is predetermined. The function specified is:

$$\text{(1)} \quad \begin{aligned} HAYP_t &= \alpha_0 + \alpha_1 HPROD_t + \alpha_2 SOYP_t + \alpha_3 INCOME_t + \alpha_4 CATTLE_t \\ &+ \alpha_5 TIME_t + e_t \end{aligned},$$

where *HAYP* is season-average hay price received by Tennessee farmers ($/ton); *HPROD* is total hay production (1,000 tons); *SOYP* is price paid by farmers for soybean meal ($/cwt.); *INCOME* is per capita income of Tennessee residents ($); *CATTLE* is Tennessee cattle and calf ending inventory for the current year, represented by January 1st inventory of the following year (1,000 head); *TIME* is time trend with 1967 = 1, 1968 = 2,...,2003 = 37; *e* is random error; α_j (j = 1...5) are parameters to be estimated (j is specific coefficient); and t is a subscript for the current year. All prices were deflated to real 2003 prices by the Gross Domestic Product Implicit Price deflator (U.S. Department of Commerce).

To clearly understand the model, a few assumptions must be made, one of which is the presence of a perfectly competitive hay market as described above. This assumption is most important and suggests that price adjusts to an equilibrium point where hay produced will satisfy its demand; price moves in such a manner as to clear the market. The other assumption is a predetermined hay supply as previously mentioned; producers are required to make their planting decisions long before time of sale.

Predetermined hay production ($HPROD_t$) is expected to have a negative sign for α_1, consistent with a negatively sloped demand curve. An increase (decrease) in the supply of a commodity will lead to a decrease (increase) in its price (Nicholson, 2002). Both Blake and Clevenger and Myer and Yanagida included predetermined hay production but found it to be insignificant in their alfalfa demand models; thus, they found alfalfa price to be unresponsive to changes in production.

Soybean meal ($SOYP_t$) price represents the price of a feed substitute. This price is predicted to positively influence the price of hay if it is a substitute in the production of livestock (Nicholson, 1997). Ostensibly, α_2 is hypothesized to have a positive sign. Blake and Clevenger represented a feed substitute price through inclusion of an April 1st price of the September corn futures contract. Soybean meal, cottonseed meal, and corn prices were assessed as proxies for prices of substitute feeds. The soybean meal price was included in the model because it fit the data best. Konyar and Knapp used a weighted average of corn, oat, and wheat prices as a proxy for the price of a feed substitute for alfalfa hay. Myer and Yanagida hypothesized other hay price as an alfalfa substitute price and showed this variable to be insignificant in their study.

Income and inventory are introduced into Equation (1) through a derived demand for hay by the livestock sector. Income and inventory are ingredients in the demand for beef, milk, and horses and are believed to positively influence the prices of beef cattle, dairy cattle, and horses, which would typically enter a derived demand equation for hay as the prices of output (Nicholson, 1997). Henceforth, per capita income ($INCOME_t$) is hypothesized to have a positive effect on $HAYP_t$ ($\alpha_3 > 0$). Cattle ($CATTLE_t$) inventory is hypothesized to have a positive impact on $HAYP_t$ Beef and dairy farmers feed hay in their operations. According to the output effect, an increase (decrease) in the price of beef and milk should act as an incentive (disincentive) for producers to increase (decrease) their input use (Nicholson, 2002). As cattle numbers fluctuate because of changing beef and milk prices, input use of hay will also fluctuate. Therefore, α_4 is hypothesized be positive. Myer and Yanagida and Konyar and Knapp showed cattle numbers to be significant in their alfalfa hay price equation. Horse inventory was not included in Equation (1) because adequate horse inventory time series data for the state were not available.

A time trend ($TIME_t$) was included to account for a negative trend in $HAYP_t$ over the time span of the study. An overall downward slide of real U.S. agricultural prices is hypothesized to be the reason for this (Gopinath et al.; U.S. Department of Agriculture, 2003). Thus, α_4 was expected to be negative due to the inner-mingling of all agricultural prices. Blake and Clevenger incorporated a time trend in their alfalfa inverse demand function and found it to have a positive effect on New Mexico hay price. They attributed a positive coefficient to an increase in cattle numbers, as well as increases in other variables.

Initially, the equation was estimated using Ordinary Least Squares (OLS). Error terms between Equation (1) and two previously estimated equations in a hay supply response study (Part 2 of this thesis) were then tested for correlation across equations. To accomplish this, Bartlett recommended testing the correlation matrix against the identity matrix with a chi-squared statistic. Correlations of residuals across the resulting equations would indicate simultaneity; a three-stage least squares approach would then be judged as the appropriate method of model estimation. However, if no correlation in error terms was found, the model would be recursive and single-equation regression methods could be used for estimation. Recursive models are characterized by their endogenous variables operating in only one direction. Equations in recursive models are arranged in such a manner that poses each equation as a function of predetermined and/or exogenous variables (Kennedy).

If the model was recursive and an equation exhibited no evidence of autocorrelation, OLS could be used. The Durbin-Watson statistic can be used to test for autocorrelation in Equation (1). A disregard of autocorrelation when present in a regression leads to consistent and unbiased estimates that are inefficient (Ramanathan). Therefore, if autocorrelation were to exist, Equation (1) would be re-estimated with a first-order autoregressive term (ρ) using Maximum Likelihood (ML).

Price flexibility values from the results of Equation (1) were calculated as follows:

$$f_{P_{H_t},X_j} = \frac{\partial HAYP_t}{\partial X_j} \times \frac{\overline{X}_j}{\overline{HAYP_t}},$$

where X represents independent variable j; and $\overline{X}$ represents the mean observation of independent variable j. $\overline{HAYP_t}$ represents the mean observation of the dependent variable $HAYP_t$. These price flexibilities show the percentage change in the hay price for a 1% change in the explanatory variable, X_1, evaluated at the means of the data.

Data

Equation (1) was estimated from annual time series data for the years 1967-2003. Data for hay production and hay price were collected from the U.S. Department of Agriculture (March 4, 2005). The soybean meal price was also taken from U.S. Department of Agriculture (1968-2004). Soybean meal price data from 1967-1985 are Tennessee prices. After this time period, statewide feed prices were no longer collected; from 1986 onward, feed prices were collected by farm production region (Williams). Therefore, 1986-2003 soybean meal price data are reflective of the Appalachian Region of the United States. This includes the states of Kentucky, North Carolina, Tennessee, Virginia, and West Virginia. Both state and regional prices are for April of their respective years (U.S. Department of Agriculture, 1968-2004). Economagic, LLC provided 1967 and 1968 Tennessee per capita income values. Tennessee per capita personal income for the years of 1969-2003 came from the Bureau of Economic Analysis (U.S. Department of Commerce). January 1st cattle inventory was collected from the U.S. Department of Agriculture (March 4, 2005). These numbers represent total head of both dairy and beef cattle in Tennessee.

Results

The Bartlett test provided a chi-squared value of 3.51 compared to a critical value of 7.81 (three degrees of freedom and a 5% significance level), which showed that the null hypothesis of no cross-correlation of errors could not be rejected. Henceforth, Equation (1) was assumed to be the last of three equations in a recursive model; the first two equations were discussed in Part 2.

A Durbin-Watson statistic of 0.89 supported the existence of positive autocorrelation. Table 1 of the Appendix gives the ML equation that includes a first order autoregressive process (AR1). All coefficient signs agreed with earlier expectations. A total R^2 value of 0.96 accompanied the coefficient estimates. The $TIME_t$ variable suggests that real hay price tended to decrease annually by an average of \$4.39/ton. Also, a \$1/cwt. change in $SOYP_t$ changed $HAYP_t$ inversely by \$0.46/ton. An inverse change in $HAYP_t$ of \$0.01/ton will occur when $HPROD_t$ changes by 1,000 tons. On the other hand, a \$0.01/ton increase (decrease) in $HAYP_t$ will usually result from a \$1.00 increase (decrease) in $INCOME_t$.

Price flexibilities are shown in table 2. Annual hay price proved to be most responsive to $INCOME_t$. For a 1% change in $INCOME_t$, $HAYP_t$ moved in the same direction by 1.55%. Other price flexibilities of interest included $HPROD_t$ at -0.31, $SOYP_t$ at 0.11, and $CATTLE_t$ at 0.17. However, ML estimates showed $CATTLE_t$ to be insignificant.

Conclusion

A price response model for the Tennessee hay market and the calculation of its corresponding flexibilities were presented. An inverse demand function was specified to reflect the components of hay demand, as well as the extent of their influences. Predetermined hay production, soybean meal price, per capita income, and a time trend significantly impacted Tennessee hay price. A first-order autoregressive term was included to adjust for autocorrelation.

Hay price appeared to be very responsive to $INCOME_t$ with a price flexibility of 1.55. This finding is reasonable to expect because an increase in real per capita income results in more purchasing power for a typical household. As purchasing power becomes greater, one could expect beef consumption to also increase because beef is usually thought of as a normal good (Schroeder and Mark). Increased beef consumption would lead to an increased derived demand for roughage and grain feed. A weak response of hay price to $HPROD_t$ can be explained by many hay producers also being livestock producers that harvest their own hay to ensure a reliable roughage supply to last their herds during the winter. These farmers may be able to produce hay at a lower cost than market price, or they may be willing to forgo the potential cost savings of buying hay from an outside source to avert feed shortages for their cattle. Regardless, the money saved and/or peace of mind gained from this could lead to utility maximization associated with risk. Lastly, a flexibility of 0.11 indicates hay price to be relatively unresponsive to $SOYP_t$. Since $SOYP_t$ was a proxy for feed substitute price, one could infer that $HAYP_t$ is fairly unresponsive to prices of other feed options.

In the future, the model could be reformulated under the assumption that year-ending hay stocks affect market price. That model could then be compared with the function presented here to determine which model best reflects Tennessee hay price determination. This study and any of its possible expansions will assist lawmakers in formulating future forage and livestock-related policies.

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Appendix

Table 1. Maximum Likelihood Estimates of Inverse Demand Equation Adjusted for First-Order Autocorrelation

Variable[a]	Coefficient	T-Value
Intercept	39.84	1.06
$HPROD_t$	-0.01***	-3.10
$SOYP_t$	0.46**	2.06
$INCOME_t$	0.01**	2.28
$CATTLE_t$	0.01	0.90
$TIME_t$	-4.39***	-3.14
AR1	-0.61***	-3.59

[a] HPROD = Tennessee hay production; SOYP = Tennessee/Appalachian Region soybean meal price; INCOME = Tennessee per capita income; CATTLE = Tennessee cattle and calf inventory; TIME = time trend; and AR1 = first-order autoregressive term.
*** and ** indicates significance at the 1% and 5% level, respectively.

Table 2. Price Flexibilities and Related Calculations

Variable[a]	Price Flexibility	Sample Mean[b]
$HPROD_t$	-0.31	2763.89 (1,000 tons)[c]
$SOYP_t$	0.11	21.10 ($/cwt.)
$INCOME_t$	1.55	19301.94 ($)
$CATTLE_t$	0.17	2438.92 (1,000 head)

[a] HPROD = Tennessee hay production; SOYP = Tennessee/Appalachian Region soybean meal price; INCOME = Tennessee per capita income; and CATTLE = Tennessee cattle and calf inventory.
[b] Hay price sample mean is 83.97 (dollars).
[c] Sample mean units are specified in parenthesis.

Part 4: Summary

This study described a recursive model representing the Tennessee hay market. Equations for hay acreage, yield, and market price were specified and their corresponding elasticities and flexibilities calculated. The acreage and yield equations reflected the dynamics of hay production over time while the inverse demand equation reflected the components of its demand. The calculation of rainfall variables and tackling the problems of multicollinearity and autocorrelation presented the greatest challenges in the completion of this research.

A ratio of lagged hay price to lagged wheat price, lagged hay acreage, and a time trend significantly impacted hay acreage. Hay yield responded to growing season rainfall, harvest season rainfall, lagged hay yield, and a time trend. Predetermined hay production, soybean meal price, per capita income, and a time trend significantly impacted Tennessee hay price. A first-order autoregressive term was included in both the acreage and price response functions to adjust for autocorrelation; no autocorrelation was shown to exist in the yield equation.

Elasticities calculated from these results indicate that Tennessee hay producers respond weakly to own and substitute crop prices. This weak response may occur because many hay producers are also cattle producers that harvest their own hay in an effort to guarantee themselves a reliable supply of roughage to last their herds throughout the winter months. They may be willing to give up potentially higher profits from a production alternative to avoid the risk of feed shortages for their cattle. This integration of hay and cattle production may explain why the acreage elasticity for lagged wheat price is small. Land in Middle and East Tennessee is less suited for row crop production as opposed to land in Western Tennessee. Fewer production substitutes for farmers in the middle and eastern parts of the state could explain a low acreage and yield elasticity for lagged own price. Row crop production may be a more suitable alternative for West Tennessee hay producers. The insignificance of lagged fescue seed price and ammonium nitrate price suggest that farmers do not respond to these input prices.

A weak responsiveness to prices by hay producers indicates that they may not attempt to purely maximize profit, but may be driven by other motivations, as well. Instead of profit maximizers, they may be utility maximizers who derive utility from profit, a rural lifestyle, a psychological connection to the land, an aversion of risk with regard to a stable roughage source, and/or other objectives.

With the exception of income, calculated flexibilities suggest that price responds weakly to economic factors. A strong response of hay price to income is reasonable to expect; an increase in real per capita income results in more purchasing power for a typical household. As purchasing power becomes greater, one could expect beef consumption to also increase since beef is considered a normal good. This increased beef consumption would lead to an increased demand for roughage and grain feed. A weak response of hay price to predetermined hay production can also be explained by many hay producers performing a dual role as livestock producers. These farmers may be able to produce hay at a lower cost than market price, or they may be willing to forgo the potential cost savings of buying hay from an outside source to avoid feed shortages for their cattle. Lastly, hay price seemed to be relatively unresponsive to prices of other feed options.

If the appropriate data became available in the future, variety-specific hay acreage response equations could be created with the purpose of comparing elasticities among the various varieties of forage crops cut for hay. Also, this model could be reformulated under the assumption that year-ending hay stocks affect market price. That model could then be compared with the equation presented in Part 3 to determine which one best reflects Tennessee hay price. The results from this research can aid lawmakers in formulating future forage, livestock, and other agricultural-related policies.

Vita

Jon Edwin Travis was born in Jackson, Tennessee, on September 25, 1980 to the Reverend Kermit "Buddy" and Patricia "Pat" Travis. He has two older sisters, Miss Julie Travis and Mrs. Jamie Travis-Gallimore, who is married to Mr. Kevin Gallimore. Jon graduated as a member of the 1999 class from Dresden High School in Dresden, Tennessee.

Jon began his higher education experience in August 1999 at The University of Tennessee at Martin (UTM). He graduated from UTM with a Bachelor of Science *Magna Cum Laude* in Agriculture (Agricultural Business Concentration) in May 2003. Then, in August 2003, he enrolled in the Agricultural Economics Master's Program at The University of Tennessee, Knoxville. He earned his Master of Science in Agricultural Economics in December 2005.

During both his undergraduate and graduate study, Jon took various courses in a wide variety of subject areas including, but not limited to: agricultural economics, animal science, economics, and natural resources. His international experience includes participating in the 2004 Kasetsart University-University of Tennessee Institute of Agriculture Student Exchange Program to Thailand. Jon's professional interests are deeply rooted in agriculture due to an upbringing on and involvement in his family's Northwest Tennessee farm.