Factors Affecting Hay Supply and Demand in Tennessee

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Abstract

Understanding the hay market is important because of hay's significance to the agriculture sector and economy. Information about acreage, yield, and price determination can assist hay producers to anticipate the demand for their product, livestock producers to comprehend the supply of a major input, and policymakers to predict the effects of proposed policies on the hay market. Results from a recursive model of the Tennessee hay market indicate that acreage and yield are price inelastic and the hay price is inflexible with respect to the quantity produced. These findings can be used to help hay and livestock producers and policymakers better anticipate the market for hay in Tennessee.

Keywords: acreage response, derived demand, elasticities, hay, inverse demand function, price flexibilities, yield response

JEL Classification: D

Factors Affecting Hay Supply and Demand in Tennessee

Understanding the interactions between supply and demand for hay is important because of hay's significance to the agricultural sector and economy, and because hay is an important crop on highly erodible soils. As an example, Tennessee has the most erodible cultivated cropland in the United States (Denton, 2000), nearly half of the state's current Conservation Reserve Program (CRP) acreage contracts are set to expire in 2007 (U.S. Department of Agriculture, 2006), and hay is one of the most economically important crops produced in the state (U.S. Department of Agriculture, 2004). Cross (1999) attributed the upward trend in Tennessee hay acreage since 1980 to an increasing number of farmers who were searching for alternative production activities, such as hay, pasture and livestock, to replace row crops on erodible soils (U.S. Congress, House of Representatives and Senate, 2002). Hay ranked tenth in value of receipts in Tennessee at $49.25 million in 2006 and cattle and calf production ranked first at $500 million. Hay ranked second in value of production at $262 million in 2003 and averaged $248 million over a five period from 2002–2006. Underscoring the importance of hay in Tennessee was the state's national ranking of fourth in the production of other hay (excluding alfalfa) at 4.25 million tons in 2006 (U.S. Department of Agriculture, 2007).

The hay market in Tennessee can be used as an example to illustrate the importance of understanding and quantifying hay supply and demand relationships more generally. With improved information, research and extension personnel can help three groups of individuals to better anticipate changes in the hay industry. First, information about the factors that affect acreage, yield, and price determination can assist hay producers to anticipate changes in the demand for their product; second, such information can help livestock producers to understand the supply of a major input in the production of their products; and third, policymakers can use the information to anticipate the effects of policies on hay and livestock producers.

To quantify these supply and demand relationships, one must understand the characteristics of hay markets. Markets are usually localized because of the weight and bulky physical characteristics of hay. Although hay species are not identical, in many livestock production situations most are close substitutes, with the possible exception of alfalfa hay. In Tennessee, alfalfa is a differentiated hay product used mostly by dairy and equine producers. Nevertheless, alfalfa constituted only 2.5% of all hay produced in Tennessee in 2003 (U.S. Department of Agriculture, 2004) and its price tends to move proportionally with other hay prices; thus, for modeling purposes alfalfa and other hay can be aggregated as in Shumway's (1983) study of Texas field crops and treated as a composite commodity (Nicholson, 2005) called hay.

The hay market in Tennessee has no substantial barriers to entry and farmers can freely exit if they choose. Large numbers of firms (hay producers) and consumers (livestock producers) exist. In 2002, 47,000 operations within the state produced forage, while on the demand side, 50,000 operations were involved in beef and dairy production with another 24,000 equine operations (U.S. Department of Agriculture, 2004). Despite the lack of national and state central markets for hay (Cross, 1999), buyers and sellers seem to be aware of the current prices in their area. Word of mouth, a hay directory website (Tennessee Farm Bureau Federation, 2005), and the *Farm Facts* bulletin (Tennessee Agricultural Statistics Service, 2004) are among the primary outlets for price discovery (Rawls, September 2004). Hay producers are typically assumed to be price takers (Shumway, 1983) because of the large numbers of sellers and buyers; nevertheless, search costs and price differentials can result from the lack of a central market.

Even though hay and livestock producers have avenues for price determination in the short run, they have little information about what causes supply and demand for hay to change from year to year. The overall objective of this research was to illustrate how the understanding of hay markets can provide valuable information to hay and livestock producers and agricultural policymakers. Using the Tennessee hay market as an example, the specific objectives were to: 1) determine the factors that influence Tennessee hay supply and quantify their effects, 2) determine the factors that influence Tennessee hay demand and quantify their effects, and 3) briefly illustrate the importance of hay supply and demand information to policymakers. Estimating factors that influence hay supply and demand can help to provide hay and livestock producers with valuable information for making more informed business decisions and policymakers with insight into how proposed agricultural policies might affect hay and livestock producers.

To accomplish the objectives, Tennessee hay supply and demand were modeled econometrically, and the coefficients of the models were used to quantify hay acreage, yield, and price responses to the factors that influence the Tennessee hay market. The results were then used to briefly illustrate the potential impacts on the 2008 Tennessee hay price from the retirement of Conservation Reserve Program (CRP) acreage in 2007.

Model Specification, Hypotheses, and Estimation Methods

Hay Supply

Literature is available regarding the determinants of perennial crop supply, but research on hay supply has received less attention than other perennial crops, and, with the exception of Shumway (1983), literature that included non-alfalfa hay was not found. Perennial supply was first modeled for apples by French (1956). French and Matthews (1971) developed a multiequation structural model to represent perennial crop supply that was illustrated using asparagus data. They estimated plantings and removals in their model. Shumway (1983) used the dual approach to estimate supply equations for six Texas field crops including hay. Blake and Clevenger (1984) developed an alfalfa hay-price forecasting model that included estimation of an alfalfa acreage equation. Elnagheeb and Florkowski (1993) compared two methods used to estimate non-bearing pecan tree numbers, one that used the methods of French and Matthews (1971) and another that used 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 (1971) method was more practical and accurate in estimating new plantings. Knapp (1987) created a dynamic equilibrium model under the rational expectations assumption that represented the California alfalfa crop. Konyar and Knapp (1988) estimated an acreage equation for California alfalfa. Knapp and Konyar (1991) examined California alfalfa production in greater depth by creating equations to specifically represent new plantings and removals. They used the Kalman filter approach to examine their model using two assumptions, naïve price expectations and quasi-rational expectations. Examples of other research on perennial crop supply included French and Bressler (1962), Bateman (1965), Behrman (1968), and Baritelle and Price (1974).

Although variables examined in the current research are relevant to the decisions to plant and remove hay from production, estimating Tennessee hay supply response to prices and other factors is not dependent on directly estimating plantings and removals in a given year or in previous years (Konyar and Knapp, 1988). Current acreage equals last year's acreage plus the difference between current-year plantings and removals. Plantings and removals for the current year are both functions of profit expectations for hay relative to competing crops and the crop life cycle. Factors that increase hay acreage do so by positively influencing plantings and negatively influencing removals in the current year, and vice versa. The crop life cycle is important because changes in current profit expectations have more influence on a farmer's decisions about early or delayed removal for a hay crop that is close to its expected useful life than for one that was established more recently. For these reasons, an acreage response model using the partial adjustment framework seems appropriate (Nerlove, 1958; Kennan, 1979; Shonkwiler and Emerson, 1982). Kennan (1979) has shown that when a decision maker is faced with a quadratic function containing both a disequilibrium cost and an adjustment cost, the partial adjustment model can serve as a description of optimal behavior. The partial adjustment framework accounts for the difference between current-year plantings and removals through current-year profit expectations. It also implicitly accounts for the difference between plantings and removals in previous years through a geometric distributed lag of historical profit expectations by including lagged acreage as an explanatory variable (Konyar and Knapp, 1988; Nerlove, 1958).

Factors that influence hay supply do so through their effects on acreage and yield. Equations (1) through (3) were specified for annual hay acreage, average yield, and production in Tennessee for 1967 through 2003:

$$(1)\qquad ACRES_t = \beta_{10} + \beta_{11}\frac{HAYP_{t-1}}{WHEATP_{t-1}} + \beta_{12}SEEDP_{t-1} + \beta_{13}ACRES_{t-1} + \beta_{14}CTIL_t + \beta_{15}LTIME_t + e_{1t},$$

$$(2)\qquad YIELD_t = \beta_{20} + \beta_{21}HAYP_{t-1} + \beta_{22}FERTP_t + \beta_{23}RAING_t + \beta_{24}RAINH_t + \beta_{25}YIELD_{t-1} + \beta_{26}TIME_t + e_{2t},$$

$$(3)\qquad HPROD_t = ACRES_t \times YIELD_t,$$

where *ACRES* is harvested hay acreage (1,000 acres); *YIELD* is state-average hay yield (tons/acre); *HPROD* is 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 national-average tall fescue seed price in April ($/cwt); *CTIL* is the percentage of Tennessee row-crop acreage (corn, cotton, sorghum, soybeans, and wheat) in no-tillage and other conservation-tillage practices (henceforth, conservation-tillage practices) between 1983 and 2003[1]; *TIME* is a time trend with 1967 = 1, 1968 = 2,…, 2003 = 37; *LTIME* is the natural logarithm of *TIME*; *FERTP* is March or April price for ammonium nitrate (AN) fertilizer in Tennessee/East South Central Region ($/ton); *RAING* is county-average cumulative rainfall during the growing season of October through November in year t-1 and February through April in year t for the top ten hay acreage counties in Tennessee (inches); *RAINH* is county-average cumulative rainfall during the harvest season of May through September in year t for the top ten hay acreage counties in Tennessee (inches); e_i (i = 1,2) 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 parameter in equation i; and t is a subscript for the current year. All prices were deflated by the index of farm production items, interest, taxes, and wage rates with 2003 = 1.0 as shown in Figure 1 (U.S. Department of Agriculture, 1967-2004A). Variable means and standard deviations are found in Table 1.

Acreage Hypotheses

Hay price expectations were represented by naïve expectations ($HAYP_{t\text{-}1}$) because the selling price is not known when hay is planted or removed from production. Potential prices to represent naïve price expectations for competing crops were lagged corn, soybean and wheat prices. The

[1] prior to 1983 CTIL = 0 for lack of data.

lagged wheat price was chosen to represent price expectations for competing crops for two reasons. First, the correlation between Tennessee wheat and corn prices for the 1967-2003 period was 0.94, and was 0.92 between wheat and soybean prices.This high correlation suggested that changes in the wheat price closely reflect changes in all three prices. Second, data from the 2002 Census of Agriculture (U.S. Department of Agriculture, 2004) indicate that most hay is produced in locations where land is prone to erosion. Larson et al. (2001) showed that a close-grown winter cover crop such as wheat reduces soil erosion. Therefore, at the margin, wheat is more competitive with hay than corn and soybeans for the same erodible land. The correlation between hay and wheat prices was 0.71, so the price ratio was used to reduce the effects of multicollinearity on the standard errors of the estimates. The hay-to-wheat price ratio is shown in Figure 2. The coefficient for $HAYP_{t\text{-}1}/WHEATP_{t\text{-}1}$ (β_{11}) in Equation (1) was expected to be positive.

The lagged tall fescue seed price ($SEEDP_{t\text{-}1}$) represented the price of an input that was expected to affect hay acreage. 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 because many farmers plant fescue in the late summer or early fall of the year preceding harvest. This schedule allows planting in more favorable weather conditions and allocates labor more smoothly over the year (Lacefield et al., 1997). Because seed is an input in the production of hay, the sign of β_{12} in Equation (1) was expected to be negative.

Lagged hay acreage ($ACRES_{t\text{-}1}$) was included in Equation (1) under the hypothesis of partial adjustment (Nerlove, 1958; Kennan, 1979; Shonkwiler and Emerson, 1982; Ramanathan, 2002). Ramanathan (2002) states that a lagged dependent variable accounts for “increasing costs associated with rapid change, or noting technological, institutional or psychological inertia.”

Inclusion of a lagged dependent variable incorporates the effects on current acreage of a geometric distributed lag of historical independent variables (Greene, 1997). In the context of partial adjustment, the coefficient for $ACRES_{t-1}$ (β_{13}) was expected to be between zero and one (Nerlove, 1958).

Cross (1999) showed that Tennessee hay acreage increased between 1980 and 1998. Further analysis showed that acreage continued to increase between 1998 and 2003. Cross (1999) attributed this increased hay acreage to an increasing number of farmers who were searching for production alternatives to annual row crops and tobacco as they tried to incorporate conservation-oriented crops such as hay into their operations (Cross, 1999; U.S. Congress, House of Representatives and Senate, 2002). The percentage of row-crop land in conservation-tillage practices ($CTIL_t$) does not directly affect hay acreage, instead government programs designed to encourage farmers to reduce soil erosion simultaneously affect both the adoption of conservation-tillage practices and the substitution of hay for row crops on highly erodible land. Thus, $CTIL_t$ was included in Equation (1) as a proxy for the increased interest and changing attitudes of farmers toward soil conservation as affected by government programs such as Conservation Compliance (Anderson and Magleby, 1997; Heimlich, 2003). Due to the dynamic factors influencing adoption and use of soil conservation practices (ie, conservation tillage, cover crops, conversion of row crops to hay production, and so forth), the sign of the coefficient for $CTIL_t$ (β_{14}) was unknown *a priori*.

A logarithmic trend was included in Equation (1) to account for the increase over time in hay acreage resulting from unspecified factors; thus, the coefficient for $LTIME_t$ (β_{15}) was expected to be positive. The logarithmic trend provided a higher R^2 than $TIME_t$ and also reduced the effects of multicollinearity on the standard errors of the coefficients for $ACRES_{t-1}$ and $CTIL_t$.

Yield Hypotheses

The lagged hay price ($HAYP_{t-1}$) and the price of ammonium nitrate (AN) fertilizer ($FERTP_t$) were included in Equation (2) to represent output price expectations and the price of an input expected to affect hay yield. As such, β_{21} and β_{22} were expected to be positive and negative, respectively. The current price of AN was used because most farmers apply nitrogen fertilizer prior to harvest in March of the current year (Bates, June 2005).

Bateman (1965) successfully incorporated weather variables in estimating Ghanaian cocoa supply response while Knapp and Konyar (1991) and French and Matthews (1971) assumed the effects of weather on yield were random disturbances included in the error term. Elnagheeb and Florkowski (1993) also attempted to include weather variables in their pecan supply response model but eventually ascribed them to the error term because of statistical insignificance. In our model, growing season rainfall ($RAING_t$) represented rainfall during the period when the majority of growth occurs in cool-season grasses (Bates, 1999; Lacefield, Henning, and Phillips, 2003). Therefore, the sign of β_{23} was expected to be positive. Harvest season rainfall ($RAING_t$) represented rainfall during the months when hay is cut (Bitzer et al., 1996). Rainfall between cuttings promotes growth; however, when exposed to rain, cut hay experiences nutrient and dry matter loss (Bates, 1994; Collins, 1983; Scarbrough et al., 2005; Smith and Brown, 1994; Sundberg and Thylén, 1994). The positive effect of rainfall on yield during the harvest season was expected to outweigh the negative effect of dry matter loss (Coblentz and Jennings, 2006; Rogers, 2007; Silvertown et al., 1994). Therefore, the sign of β_{24} was expected to be positive.

The remaining variables were included to account for partial adjustment ($YIELD_{t-1}$) (Nerlove, 1958) and improvements in yield-increasing technology over time ($TIME_t$). The coefficient for $YIELD_{t\text{-}1}$ (β_{25}) was expected to be between zero and one, and the coefficient for $TIME_t$ (β_{26}) was expected to be positive.

Hay Demand

Hay supply is predetermined by current-year plantings, removals and weather, and once produced, most hay is consumed by livestock during the winter before the next harvest season (U.S. Department of Agriculture, 2004). An inverse demand function with hay price as the dependent variable is appropriate when supply is predetermined (Blake and Clevenger, 1984; Myer and Yanagida, 1984). The inverse demand function was specified for 1967 through 2003 as:

$$(4) \qquad HAYP_t = \beta_{40} + \beta_{41}HPROD_t + \beta_{42}SOYP_t + \beta_{43}INCOME_t + \beta_{44}CATTLE_t + \beta_{45}TIME_t + e_{4t},$$

where *HAYP* is season-average hay price (May 1 of current year to April 30 of following year) received by Tennessee farmers ($/ton); *HPROD* is hay production (1,000 tons); *SOYP* is Tennessee/Appalachian region soybean meal price ($/cwt); *INCOME* is per capita income for Tennessee ($); *CATTLE* is Tennessee cattle and calf inventory on December 31 of the current year (beef and dairy), represented by January 1 inventory of the following year (1,000 head); *TIME* is a time trend with 1967 = 1, 1968 = 2,…, 2003 = 37; e_4 is a random error; β_{4j} (j = 0,…,5) are parameters to be estimated; and t is a subscript for the current year. All prices and per capita income were deflated by the Gross Domestic Product Implicit Price Deflator with 2003 = 1.0 (U.S. Department of Commerce, 2005). Variable means and standard deviations are found in Table 1.

Price Hypotheses

The coefficient for $HPROD_t$ (β_{41}) was expected to be negative, consistent with a negatively sloped industry demand curve (Blake and Clevenger, 1984; Myer and Yanagida, 1984). The soybean meal price (*$SOYP_t$*) represented the price of other feeds. As such, β_{42} was hypothesized to have a positive sign. Blake and Clevenger (1984) represented the price of other feeds with the April 1st price of a September corn futures contract. They also considered the soybean futures price, but chose the corn futures price because of its significance. We considered the prices of corn, soybean meal, and cottonseed meal as potential variables to represent prices of other feeds. Prices of ingredients in feed rations tend to move together because the ingredients are generally good substitutes (Blake and Clevenger, 1984). Correlation coefficients for soybean meal, corn, and cottonseed meal prices with the hay price over the sample period were 0.71, 0.82, and 0.69, respectively. When the corn price or the cottonseed meal price were used to represent other feed prices, multicollinearity seriously inflated the standard errors of several coefficients in the equation and some coefficients, including the coefficient for the price of corn, had unexpected signs. The soybean meal price was use to represent the prices of substitute feeds because it produced a higher R^2 than cottonseed meal or the corn price, and multicollinearity did not inflate the standard errors or produce unexpected signs of the coefficients.

Typically, the derived demand for a production input is a function of the price of the input, prices of other inputs, and output prices (Nicholson, 2005). Income and inventory are introduced into Equation (4) through the derived demand for hay by the livestock sector; thus, Equation (4) represents a reduced form equation where the determinants of demand for livestock products (e.g., milk and beef) are substituted into Equation (4) for the prices of those products. An increase in the price of beef or milk would act as an incentive for livestock producers to increase input use (Nicholson, 2005) as they build their herds. Beef and milk are typically normal goods, so an increase in per capita income would increase the demand for livestock products, increasing their prices over time, which in turn would increase the price of hay as the demand for hay increases when farmers build their herds in anticipation of future profits. Myer and Yanagida (1984) and Konyar and Knapp (1988) included cattle numbers in their alfalfa hay price equation. As past changes in livestock product prices and income affect current cattle and calf inventory, the demand for hay as an input would also change. The hay price ($HAYP_t$) was expected to be positively related to both per capita income ($INCOME_t$) and cattle and calf inventory ($CATTLE_t$) in Equation (4); thus, β_{43} and β_{44} were hypothesized to be positive.

A time trend ($TIME_t$) was included to account for a negative trend in $HAYP_t$ over time (Figure 1). The trend variable captures the effects of other variables not included in the model that have influenced the downward slide of real U.S. agricultural prices (Gopinath et al., 1997). Thus, β_{45} was hypothesized to be negative compared to the null hypothesis of trend stationarity in hay prices.

Statistical Methods

To test for simultaneity in the model, Equations (1), (2), and (4) were first estimated with Ordinary Least Squares (OLS) and the residuals were tested for correlation across equations using a test proposed by Bartlett (1954). His test uses a chi-squared statistic to compare the residual correlation matrix against the identity matrix. Correlation of errors across equations implies simultaneity and estimating the system of equations with three-stage least squares would be most appropriate (Greene, 1997). However, if error terms are uncorrelated, the model would be recursive and, in the absence of autocorrelation, OLS would be an appropriate single-equation estimation method for each equation. If the Durbin-H statistic calculated from the OLS estimation of Equations (1) and (2) or the Durbin-Watson statistic from Equation (4) indicated autocorrelation for a particular equation (Greene, 1997), the equation would be re-estimated with a first-order autoregressive term (*AR1*) using Maximum Likelihood (ML) as the single-equation estimation method.

Short-run and long-run elasticites (Nerlove, 1958) were calculated from the results of Equations (1) and (2) and price flexibilities were calculated from the results of Equation (4). Elasticities and flexibilities were calculated at the means of the variables. These estimated elasticities and flexibilities are the quantified effects of the explanatory variables on hay acreage, yield and price that can be used to help hay and livestock producers make more informed business decisions and policymakers anticipate the effects of proposed agricultural policies on those producers.

Data

Data for hay acreage, price, yield, and season-average wheat price were taken from U.S. Department of Agriculture (2005). Figure 3 shows the number of acres in hay production and Figure 4 shows the average hay yield (tons/acre) in Tennessee from 1966 to 2006. The national average retail price for tall fescue seed was from U.S. Department of Agriculture (1967-2004B). Seed prices for 1968-2003 were for April. The seed price for 1967 was the U.S. February-May season-average price. The AN price was taken from U.S. Department of Agriculture (1967-2004A). Price data for AN 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, January 2005). Tennessee AN prices were available for 1967-1976. Prices of AN for the East South Central Region were used thereafter (U.S. Department of Agriculture, 1967-2004A). Data for the percentage of Tennessee row-crop acreage in conservation-tillage practices were from Tennessee Department of Agriculture (1996-2003, July 2004).

Growing and harvest season rainfall for the top ten hay acreage counties were collected from the National Climatic Data Center (U.S. Department of Commerce, 2005). 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, 2005). Missing observations were replaced by rainfall from the neighboring county that shares the longest border.

Results

The Bartlett (1954) test did not reject the null hypothesis of no cross-equation correlation of errors ($\chi^2 = 3.51$; 3 df; $\alpha = 0.05$), suggesting that the hay market can be represented by a recursive model. The Durbin-H statistics calculated from the OLS acreage and yield equations were -4.28 and -1.39, respectively, rejecting ($\alpha = 0.05$) the null hypothesis of no autocorrelation for Equation (1) but not for Equation (2). A Durbin-Watson statistic of 0.89 led to rejection of the null hypothesis of no autocorrelation for Equation (4). Thus, Equations (1) and (4) were estimated with ML and Equation (2) was estimated with OLS (Tables 2, 3, and 4).

Hay acreage

All coefficients in the hay acreage equation (Table 2) had their hypothesized signs and were statistically significant, except the coefficient for $SEEDP_{t\text{-}1}$, which was not significant. The first-order autoregressive parameter (*AR1*) was significantly different from zero at the 1% level. Hay acreage elasticities for the ratio of expected hay-to-wheat prices ($HAYP_{t\text{-}1}/WHEATP_{t\text{-}1}$) were small in the short and long runs, suggesting that farmers increased hay acreage by 0.08% and 0.20%, respectively, for a 1% increase in the ratio of expected prices. Also, government conservation programs appear to have had a smaller influence on hay acreage than on conservation-tillage practices. The short- and long-run elasticities for $CTIL_t$ were 0.05 and 0.12, respectively. The interpretation of these elasticities is as follows: if government conservation programs influenced farmers to increase the percentage of row-crop acreage in conservation-tillage practices ($CTIL_t$) by 1%, they also encouraged farmers to increase hay acreage by 0.05% in the short run and 0.12% in the long run. Results suggest that government conservation programs had a greater positive impact on the conversion of row-crop acreage to conservation-tillage practices than on the conversion of row-crop acreage to hay production.

Hay Yield

The signs of all coefficients met *a priori* expectations in the yield equation (Table 3). The two rainfall variables, lagged yield, and the time trend had coefficients that were significantly different from zero, albeit only at the 10% level for the rainfall variables. Collinearity diagnostics (Belsley, Kuh, and Welsch, 1980) indicated evidence of multicollinearity between the intercept and $HAYP_{t-1}$ at a condition index of 55 and among HAYP_{t-1}, YIELD_{t-1}, and TIME_t at a condition index of 35; thus, the standard error of the coefficient for $HAYP_{t-1}$ may have been seriously degraded by multicollinearity, and failure to reject the null hypothesis may be misleading (Belsley, Kuh, and Welsch, 1980). Nonetheless, hay yield was unresponsive to changes in both the expected hay price ($HAYP_{t-1}$) and the price of nitrogen fertilizer ($FERTP_t$), which had short-run yield elasticities of 0.13 and -0.07, respectively. In the short run, 1% increases in growing season ($RAING_t$) and harvest season ($RAINH_t$) rainfalls were accompanied by hay yield increases of 0.12% and 0.14%, respectively, and in the long run the respective increases were 0.19% and 0.22%. A one standard deviation reduction from the mean in $RAING_t$ of 4.1 inches (19% reduction) would result in a yield decline of 2.3% in the short run and 3.1% in the long run. Similar results for $RAINH_t$ (18% reduction) are a 2.5% reduction in yield in the short run and a 4.0% reduction in the long run.

Hay Price

The hay-price equation (Table 4) had coefficients with signs that met prior expectations. Only cattle and calf inventory ($CATTLE_t$) had a coefficient that was not significantly different from zero. Annual hay price was most responsive to real per capita income ($INCOME_t$).[1] For a 1% change in real per capita income, the hay price moved in the same direction by 1.55%. The hay-price flexibility with respect to hay production $HPROD_t$ was estimated at -0.31, suggesting that the hay price was fairly unresponsive to quantity. If demand were quantity dependent, this price flexibility would correspond to an own-price elasticity of demand of -3.23, the inverse of the price flexibility. The price flexibility for $SOYP_t$ was 0.11, suggesting that an increase in the soybean meal price of 1% would be accompanied by a 0.11% increase in the hay price.

Brief Policy Example

The results presented above can be used to help hay and livestock producers and policymakers anticipate changes in the Tennessee hay market. For example, with an estimated 120.5 thousand acres in Tennessee and 15.6 million acres in the United States under CRP contract set to expire on August 30, 2007 (U.S. Department of Agriculture, 2006), the impact on hay markets is of interest to farmers and policymakers alike. These acreages represent 44% of the total Tennessee CRP land and 43% of the total U.S. CRP land under contract. A complete analysis of the Tennessee hay-market impacts of this CRP acreage expiration would require evaluation within a national context. Such an evaluation is contemplated for future research, but a rough example illustrates the potential usefulness of the results presented above. Hellwinckel and De La Torre Ugarte (2006) estimated that 2.7% (3.2 thousand acres) of the 120.5 thousand acres of Tennessee CRP land set to expire in 2007 will be used for hay production in 2008. Assuming the mean of hay acreage used in this study (1,483.2 thousand acres), this change represents a 0.2% increase in

Tennessee hay production, assuming hay yield is unaffected. Applying this 0.2% production increase to the 0.31% price flexibility estimated from Equation (4) gives a decline in the 2008 Tennessee hay price of 0.07%. Notably, the predicted impact of the 2007 CRP expiration on the 2008 hay price is small, suggesting that the impacts on acreage and yield in succeeding years also will be small. Further, CRP contract expirations in succeeding years are smaller than in 2007, suggesting that impacts in those years will be even smaller and that the cumulative impacts on the Tennessee hay market will probably be slight.

Conclusions

Tennessee hay acreage proved to be fairly unresponsive to output and input prices in both the short and long runs. The weak response of hay acreage to own and substitute crop prices may result from many hay producers also being cattle producers that harvest their own hay in an effort to guarantee a reliable supply of roughage to feed their herds throughout the winter months. They might be willing to give up potentially higher profits from a production alternative to avert the risk of feed shortages for their cattle. Konyar and Knapp (1988) came to a similar conclusion in regard to a reliable roughage supply. The possibility of risk in livestock production may explain why the hay acreage elasticity for the expected ratio of hay-to-wheat prices is small. Also, a substantial number of hay producers reside in Middle and East Tennessee (U.S. Department of Agriculture, 2004). Land in these areas of the state is less suited for row-crop production compared to land in West Tennessee. Fewer production substitutes for Middle and East Tennessee farmers could explain the weak response of hay acreage to expected output prices.

The hay price appeared to be responsive to real per capita income with a price flexibility of 1.55. This finding is expected because an increase in real per capita income results in more purchasing power for a typical household. As purchasing power increases, one would expect beef consumption to increase because beef is a normal good (Schroeder and Mark, 1999). Increased beef consumption would positively influence the derived demand for beef production inputs; hence, increased demand for hay.

A weak response of hay price to the quantity of hay produced ($HPROD_t$) could be explained by the hay market structure. First, some livestock farmers may produce large amounts of hay for their own livestock, much of which is not sold on the market. 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 from buying hay from an off-farm source to avert the risk of feed shortages for their cattle. Additionally, unlike the market for corn or cattle, the hay market is much less organized and structured. Farmers producing hay for the cash market have no nearby and convenient grain elevator or auction market at which to sell their product. Also, hay is not a single "crop" like soybeans, but many different "crops" in terms of species of hay (alfalfa to tall fescue), quality (high to low) and bale packaging (small square to large round). Unlike wheat or cattle, there are no standardized grades used in the industry as a measure of quality or value. Weak response to changes in hay quantity suggests that hay farmers may not be driven solely by the profit motive. Instead, other motives may also enter into their objective functions as utility maximizers.

The small price elasticities for acreage and yield estimated in this research along with the relative unresponsiveness of the hay price to changes in quantity suggest that the Tennessee hay market is fairly stable in the short and long runs. Changes in the prices of alternative crops, prices of inputs, and weather showed relatively small effects on hay production and prices. Thus, policy impacts, such as the expiration of CRP contracts, would likely have small impacts in both the short and long run. Even though a potential policy change may result in a small overall average impact, small changes in input prices could have large economic and personal impacts on marginal producers. Consequently, the results from this research can be used by policymakers to investigate the average effects of agricultural policies on the hay market, but to make better business decisions, individual hay or livestock producers should assess their own situations in relation to the average impacts.

Further research to transfer this modeling approach to other southern states would provide insight into whether hay markets in those states are similar to the Tennessee hay market in their responses to changes in prices and quantity. Especially useful would be to determine whether differences in elasticities are more pronounced for hay markets in states outside the southern region. Linking a set of state models with a U.S. model would also be useful in capturing differential impact of broad policy changes among geographically diverse hay markets.

Endnote

1. Theoretically, using U.S real per capita income may be more appealing than using Tennessee real per capita income. Still, these two measures of income are highly correlated (0.99). The more geographically targeted Tennessee real per capita income was used because, when U.S. real per capita income was included in the Tennessee real hay price equation, its standard error was inflated by multicollinearity making interpretation of its coefficient difficult. Further, the resulting R^2 was lower than when the more geographically targeted Tennessee real per capita income was used.

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Table 1. Names, Definitions, Means, and Standard Deviations of the Variables Used to Estimate the Hay Acreage, Yield, and Price Equations, 1967-2003

Variable	Definition	Mean	Std. Dev.
$ACRES_t$	Tennessee harvest hay acreage (1,000 acres)	1,483.24	304.97
$HAYP_{t-1}/WHEATP_{t-1}$	Season-average hay to wheat price ratio lagged one year	17.30	3.82
$HAYP_{t-1}$	Season-average hay price received by Tennessee farmers lagged one year ($/ton) [a]	83.89	26.31
$WHEATP_{t-1}$	Season-average wheat price received by Tennessee farmers lagged one year ($/bu) [a]	5.02	1.75
$SEEDP_{t-1}$	U.S average tall fescue seed price in April lagged one year ($/cwt) [a]	106.52	20.66
$ACRES_{t-1}$	$ACRES_t$ lagged one year (1,000 acres)	1,459.62	295.13
$CTIL_t$	Percentage of Tennessee row-crop acreage in no-tillage and other conservation-tillage practices	29.71	30.76
$TIME_t$	Time trend with 1967 = 1, 1968 = 2, …, 2003 = 37	19.00	10.82
$LTIME_t$	The natural logarithm of $TIME_t$	2.68	0.87
$YIELD_t$	Tennessee-average hay yield (tons/acre)	1.81	0.31
$FERTP_t$	Ammonium nitrate fertilizer price in Tennessee/East South Central Region ($/ton) [a]	262.42	52.61
$RAING_t$	County-average cumulative rainfall for October and November of year *t-1* and February through April of year *t* in the top 10 Tennessee hay acreage counties (inches)	21.60	4.06
$RAINH_t$	County-average cumulative rainfall for May through September of year *t* in the top 10 Tennessee hay acreage counties (inches)	21.74	3.94
$YIELD_{t-1}$	$YIELD_t$ lagged one year	1.79	0.30
$HAYP_t$	Season-average hay price received by Tennessee farmers ($/ton) [b]	83.97	24.72
$HPROD_t$	Tennessee hay production (1,000 tons)	2,763.89	1,018.83

$SOYP_t$	Tennessee/Appalachian Region soybean meal price ($/cwt) [b]	21.10	5.86
$INCOME_t$	Tennessee per capita income ($) [b]	19,301.94	5,414.78
$CATTLE_t$	Tennessee cattle and calf inventory on December 31 of year *t* (1,000 head)	2,438.92	264.14

[a] Deflated by the Index of Farm Production Items, Interest, Taxes, and Wage Rates with 2003 = 1.0 (U.S Department of Agriculture, 1967-2004A).
[b] Deflated by the Gross Domestic Product Implicit Price Deflator 2003 = 1.0 (U.S Department of Commerce, 2005).

Table 2. Maximum Likelihood Estimates of the Hay Acreage Equation Adjusted for First-Order Autocorrelation, with Accompanying Short- and Long-Run Elasticities at the Means, 1967-2003

Variable [a]	Coefficient	T-Statistic	Short-Run Elasticity	Long-Run Elasticity
Intercept	251.89*	1.94		
$HAYP_{t-1}/WHEATP_{t-1}$	6.84***	2.87	0.08	0.20
$SEEDP_{t-1}$	-0.02	-0.04	-0.001	-0.002
$ACRES_{t-1}$	0.59***	4.71		
$CTIL_t$	2.56**	2.58	0.05	0.12
$LTIME_t$	64.48***	3.42		
AR1 [b]	0.47**	2.64		
Total R^2	0.96			
OLS Durbin-H	-4.28***			

[a] The dependent variable is $ACRES_t$. Definitions of the variables are found in Table 1.
[b] *AR1* is the first-order autoregressive term.
***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 3. Ordinary Least Squares Estimates of the Hay Yield Equation, with Short- and Long-Run Elasticities at the Means, 1967-2003

Variable [a]	Coefficient	T-Statistic	Short-Run Elasticity	Long-Run Elasticity
Intercept	0.17	0.39		
$HAYP_{t-1}$	0.003	1.11	0.13	0.20
$FERTP_t$	-0.0005	-0.87	-0.07	-0.11
$RAING_t$	0.01*	1.68	0.12	0.19
$RAINH_t$	0.01*	1.78	0.14	0.22
$YIELD_{t-1}$	0.38**	2.43		
$TIME_t$	0.02***	2.72		
R^2	0.84			
OLS Durbin-H	-1.54			

[a] The dependent variable is $YIELD_t$. Definitions of the variables are found in Table 1.
***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 4. Maximum Likelihood Estimates of the Inverse Demand Equation Adjusted for First-Order Autocorrelation, with Hay Price Flexibilities at the Means, 1967-2003

Variable [a]	Coefficient	T-Statistic	Hay Price Flexibility
Intercept	39.84	1.06	
$HPROD_t$	-0.01***	-3.10	-0.31
$SOYP_t$	0.46**	2.06	0.11
$INCOME_t$	0.01**	2.28	1.55
$CATTLE_t$	0.01	0.90	0.17
$TIME_t$	-4.39***	-3.14	
AR1 [b]	-0.61***	-3.59	
Total R^2	0.96		
OLS Durbin-Watson	0.89**		

[a] The dependent variable is $HAYP_t$. Definitions of the variables are found in Table 1.

[b] *AR1* is the first-order autoregressive term.

*** and ** indicate significance at the 1% and 5% levels, respectively.

Figure 1. Tennessee Deflated Hay Price from 1966 to 2006.

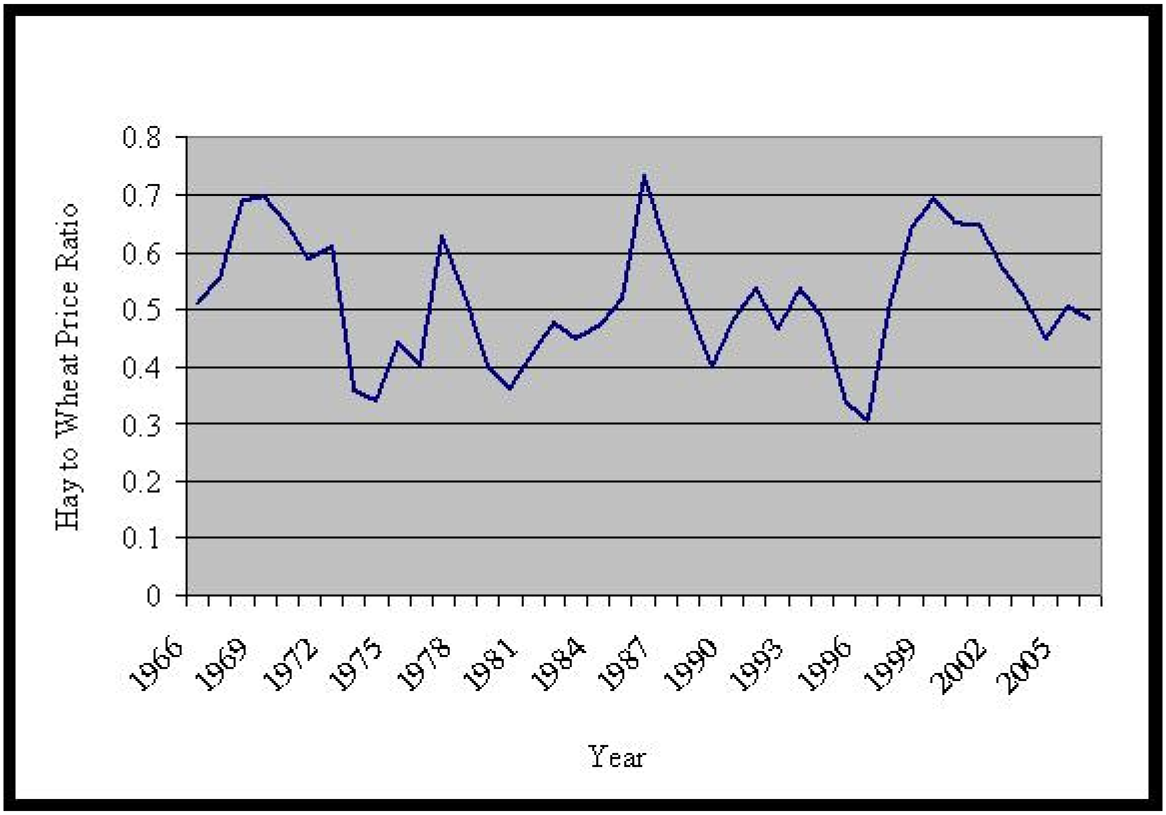

Figure 2. Tennessee Hay-to-Wheat Price Ratio from 1966 to 2006.

Figure 3. Tennessee Hay Acreage from 1966 to 2006.

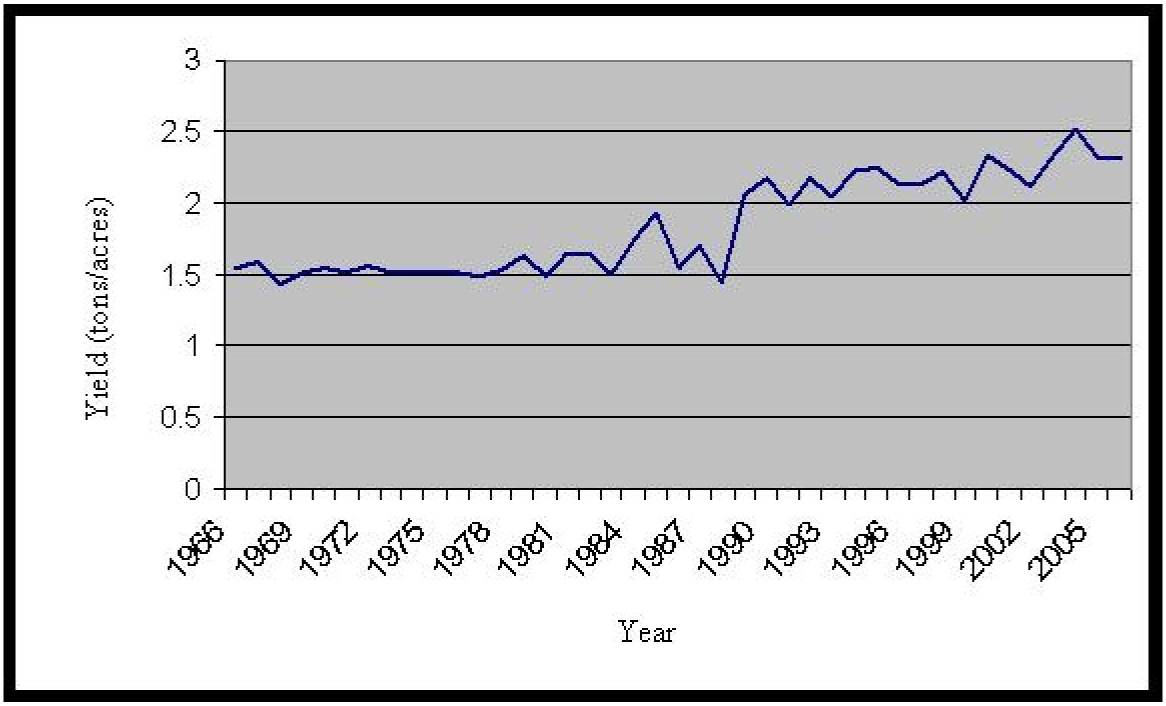

Figure 4. Tennessee Hay Yield from 1966 to 2006.