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Practitioner's Abstract

The Renewable Fuel Standard mandates in the Energy Independence and Security Act of 2007 (EISA 2007) will require 36 billion gallons of ethanol to be produced in 2022, 16 billion gallons of which is to be produced from cellulosic feedstocks. To meet the mandate, it is estimated that 24.7 million acres would be used to produce 109 million tons of switchgrass in 2025. Since the majority of these acres likely would be converted from land currently producing hay, cattle production will be reduced. As a step toward understanding the impacts of biofuel mandates on cattle markets, a linkage between hay production and hay prices needs to be established. For lower quality hay, the results indicate that a 10% decrease in Oklahoma production led to a 5% increase in Oklahoma price. For all hay, including higher quality alfalfa hay, the price increase was only 2% because of the large effect of Texas hay production.

Keywords: biofuels, mandates, switchgrass, hay markets.

Introduction

The Renewable Fuel Standard mandates in the Energy Independence and Security Act of 2007 (EISA 2007) will require 36 billion gallons of ethanol to be produced in 2022, 16 billion gallons of which is to be produced from cellulosic feedstocks. To meet the mandate, 24.7 million acres would be used to produce 109 million tons of switchgrass in 2025. The majority of these acres would be converted from land currently producing hay (Dicks et al. 2009).

Reduced hay production is important because of hay's significance to the agricultural sector. Hay production in the U.S. was 145.67 million tons valued at $18.78 billion (NASS 2008). It is an especially important crop on highly erodible soils (Bazen et al. 2008).

Dicks et al. (2009) predicted, using POLYSYS, that hay production would be reduced by 15.4 million acres (almost 20% of forage acres), leading to a 13.1-million-head reduction in beef cows. Their analysis described several areas that could benefit from further research including an estimate of the beef cow – hay price relationship. Because reliable information on hay market price response was not available for the study by Dicks et al (2009), the predicted effect on beef cows came from a simplistic estimate that reduced beef cow numbers based solely on the tons of forage no longer produced – since each cow needs approximately 1,000 pounds of forage per month, replacing forage with switchgrass-for-ethanol would correspondingly reduce the number of cows that could be produced. To fully understand the impacts of biofuel mandates on cattle markets a linkage between cattle numbers and hay prices needs to be established. As a first step, this research estimates the effect of hay production on hay prices by estimating the (inverse) demand for hay, with hay price as a function of hay production, cattle numbers, and price of substitutes for hay.

Objective and Procedures

The objective of the analysis is to determine the impact of changes in hay production in Oklahoma and surrounding states on changes in price of hay in Oklahoma. The results will be used in ongoing research to determine the effects of increased switchgrass production on hay prices, and in turn on profitability of cattle production.

Konyar and Knapp (1990) modeled price of hay as a function of alfalfa production, feed, livestock prices, and animal inventory. Blake and Clevenger (1984) modeled quantity as a function of corn price and a trend. Bazen et al. (2008) modeled Tennessee hay price as a function of hay production, price of soybean, cattle and calf inventory, income, and time trend and found all variables attaining their expected signs. Diersen (2008), noting the importance of hay in the national crop mix, developed a balance sheet model to forecast the price of hay in South Dakota.

A complication in modeling hay prices is that hay markets are thin, with hay prices established by relatively few transactions. Since hay is a bulky commodity, transporting hay long distances is expensive relative to the value of hay, so most hay is used locally. Much of it likely is used on the farms on which it was produced, without entering the market.

Here, a price-dependent (inverse) demand equation for hay in Oklahoma is specified as a function of quantity of hay produced in Oklahoma and surrounding states, quantity of beef cows in Oklahoma and surrounding states (since demand for hay is a derived demand from cattle production; beef cows are heavily dependent on lower-quality hay, while dairy cows and horses are more dependent on high quality hay), and price of substitutes. It is expected that higher numbers of beef cows will increase quantity of hay demanded and thus price, while increased production of hay will decrease its price. Price of soybeans represents price of protein supplements, which can be viewed as substitutes for hay, so increases in price of soybeans should be associated with increases in price of hay.

Annual data were obtained from 1974-2008 for Oklahoma and surrounding states from NASS. A statistical summary of the data is presented in Table 1. A key feature of the data apparent in this summary is that Texas hay production and beef cow numbers are nearly double or more than double those of Oklahoma. Another key feature not apparent in the summary, but shown in Figures 1 and 2, is the upward trend over this time period in both hay production and prices.

Because both Texas hay production and beef cow numbers are high relative to Oklahoma, the hay production variables were normalized by dividing Texas hay production in each year by Texas beef cow numbers in January of the following year, and Oklahoma hay production in each year by Oklahoma beef cow numbers in January of the following year. This restates both Oklahoma and Texas hay production in terms of tons of hay per cow.

Each of the data series was checked for stationarity using a Dickey-Fuller unit root test. While a unit root was rejected at the 5% level for Texas and Oklahoma hay production per cow, and price of soybeans, and at the 10% level for price of all hay, it was not rejected at even the 10% level for price of other hay. A unit root was rejected strongly for all of these series when each series was transformed by differencing its natural log.

Two models were estimated by Generalized Least Squares, allowing for an autoregressive term of order 1. In the first model, Oklahoma price of all hay from 1974-2008 was specified as a function of Oklahoma production of all hay divided by number of beef cows in Oklahoma, Texas production of all hay divided by number of beef cows in Texas, a trend variable – following Blake and Clevenger (2004), and Bazen et al. (2008) – and price of soybeans.

In the second model, Oklahoma price of other hay (all hay except alfalfa) was specified as a function of Oklahoma production of other hay divided by number of beef cows in Oklahoma, Texas production of other hay divided by number of beef cows in Texas, a trend variable, and price of soybeans. Because alfalfa is a high quality, higher-priced hay, it is less likely to be replaced by switchgrass mandates, so other hay (excluding alfalfa) likely represents better the kind of hay that would be replaced by increased production of switchgrass. Unfortunately, since data for price of other hay was not available until 1989, this second model was estimated over the period for 1989-2008.

Results

Table 2 indicates that for the first model, Oklahoma price of all hay, estimated coefficients all have the expected signs, although the time trend is significant at only the 14% level and the coefficient of *ln(OK Hay/OK Cows)* is significant at only the 12% level. Since the variables are in natural logs, this coefficient (-0.191) indicates that a 10% reduction in Oklahoma hay production, holding everything else constant, was associated with a 1.91% increase in Oklahoma hay price. The coefficient of *ln(TX Hay/TX Cows)* indicates that a 10% reduction in Texas hay production was associated with a 3.67% increase in Oklahoma hay price, nearly twice as large an effect as Oklahoma production. That coefficient is more statistically significant as well. This indicates that the market for hay crosses state lines, and analysis of hay markets must take into account supply and demand factors in neighboring states. For example, an extended drought in Texas is likely to raise hay prices in Oklahoma.[1]

In contrast, Table 3 indicates that for Oklahoma price of other hay, estimated coefficients all have the expected signs, except that the coefficient of *ln(TX Hay/TX Cows)* is positive but highly insignificant. While the estimated coefficient of *ln(OK Hay/OK Cows)* indicates that a 10% reduction in production of other hay was associated with a 5.25% increase in Oklahoma price of other hay, the effect on Oklahoma price of a reduction in Texas production of other hay was effectively zero.

The difference between the results for all hay and the results for other hay likely is because higher value alfalfa, which is included in all hay but not in other hay, is transported in greater quantities and greater distances than non-alfalfa hay. It is more likely to cross state lines, so that Texas production has a greater effect on Oklahoma's price in the market for all hay than in the market for other hay.

As Renewable Fuel Standard mandates are implemented, the increased profitability of switchgrass production will bid resources (especially land) away from hay production. This analysis has provided estimates of the effect of hay and cattle production on hay prices in Oklahoma. As hay prices increase, cattle production will become more expensive, and unless

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[1] Using hay production to beef cow numbers ratios for Arkansas and Kansas added no explanatory power to the Oklahoma price model, and the coefficients for those variables were statistically insignificant.

cattle prices increase substantially, cattle production will decrease. Research in progress is measuring the effect of increased hay prices on cattle production.

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Table 1. Data Statistics

Variable	units	Mean	Std. Dev.	Min	Max	n
Price of All Hay (OK)	$/ton	70.30	15.20	45.50	117.00	35
Price of Other Hay (OK)	$/ton	57.38	9.92	44.50	88.00	20
Production of All Hay (OK)	1,000 tons	4,274	992	2,315	6,858	35
Production of All Hay (TX)	1,000 tons	8,397	2,544	5,106	14,740	35
Production of Other Hay (OK)	1,000 tons	3,576	825	2,470	5,600	20
Production of Other Hay (TX)	1,000 tons	7,701	2,600	4,160	14,040	35
Beef Cows (OK)	1,000 head	2,038	214	1,799	2,673	35
Beef Cows (TX)	1,000 head	5,626	444	5,110	6,482	35
Price of Soybeans (OK)	$/bu	5.95	1.28	4.25	10.00	35

Table 2. Factors Explaining Price of All Hay 1974-2008

Variables	Coefficient	Std. Error	t-statistic	p-value
Constant	0.107	0.051	2.110	0.044
ln(Time)	-0.027	0.018	-1.503	0.144
ln(OK Hay/OK Cows)	-0.191	0.119	-1.602	0.120
ln(TX Hay/TX Cows)	-0.367	0.120	-3.061	0.005
ln(Price OK Soybeans)	0.244	0.092	2.654	0.013
Rho (AR1)	-0.651	0.159	-4.096	0.000

N = 34, df = 28, DW = 2.38, Adj $R^2 = 0.455$

Table 3. Factors Explaining Price of Other Hay 1989-2008

Variables	Coefficient	Std. Error	t-statistic	p-value
Constant	-0.280	0.392	-0.714	0.488
ln(Time)	0.090	0.121	0.747	0.468
$\Delta_{t-1,t}$ *ln(OK Hay/OK Cows)*	-0.525	0.183	-2.866	0.013
$\Delta_{t-1,t}$ *ln(TX Hay/TX Cows)*	0.018	0.157	0.117	0.909
$\Delta_{t-1,t}$ *ln(Price OK Soybeans)*	0.309	0.170	1.820	0.092
Rho (AR1)	-0.220	0.410	-0.536	0.601

N =19, df =13, DW =1.95, Adj $R^2 = 0.464$

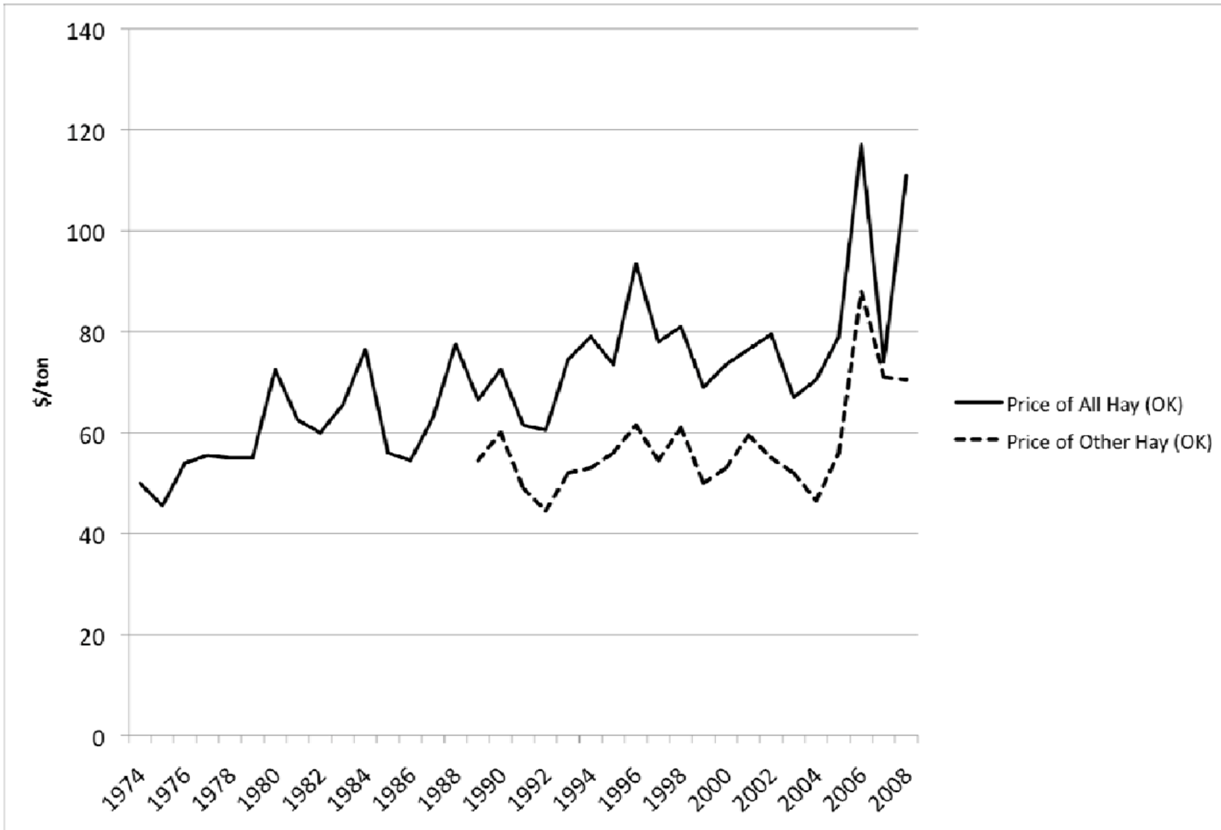

Figure 1. Price of Oklahoma Hay, 1974-2008

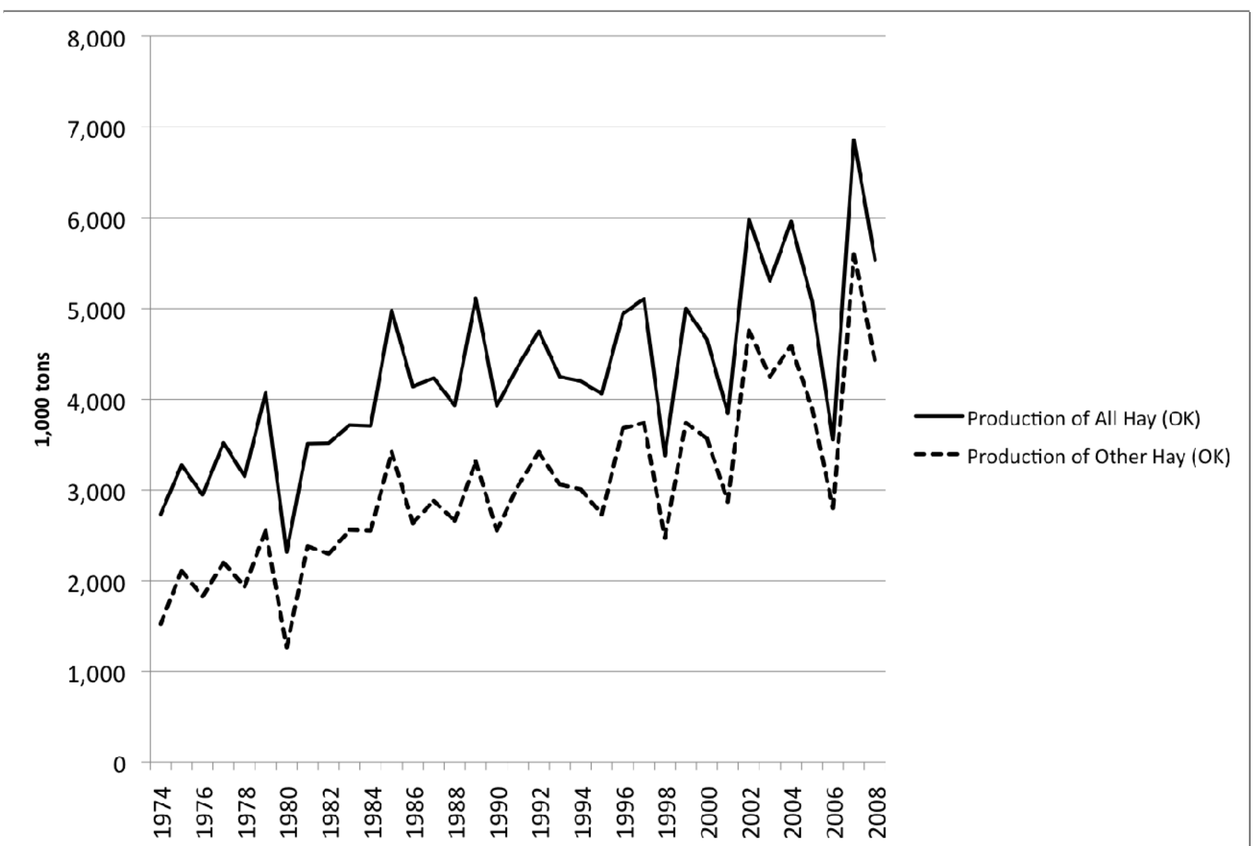

Figure 2. Production of Oklahoma Hay, 1974-2008