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Hay Supply in The U.S. Midwest

Ana Stepanovic
University of Nebraska-Lincoln, ana.stepanovic87@gmail.com

HAY SUPPLY IN THE U.S. MIDWEST

By

Ana Stepanovic

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Ana Stepanovic, M.S.

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Adviser: Richard Perrin

The Renewable Fuel Standard (RFS) mandates in the Energy Independence and Security Act (EISA) of 2007 require that 36 billion gallons of renewable biofuels be produced in 2022, of which 16 billion gallons are to be from cellulosic feedstocks. This study examined supply of “other hay” (hay excluding alfalfa), based on the assumption that "other hay" is similar to grass species that might be grown as cellulosic feedstock. We have attempted to estimate the factors affecting the acreage of "other hay" in the context of a system of equations explaining allocations among all crops. For each of the three basic models (acreage allocation equations, acreage share equations and revenue share equations), we have estimated with seemingly unrelated regression (SUR) and three-stage least squares (3SLS). Empirical analysis reveals that production of hay in Upper Midwestern U.S. has not been significantly and consistently affected by prices.

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1. Introduction

Security concerns for fuel which is derived from petroleum and issues of climate change encouraged the search for alternative ways of supplying fuel, including biofuels. Biofuel can be produced from grains or sugars, or from several different cellulosic sources, including forest resources, crop residues, woody biomass, and perennial grasses (switchgrass, grass hay). The Renewable Fuel Standard (RFS) mandates in the Energy Independence and Security Act (EISA) of 2007 require that 36 billion gallons of renewable biofuels be produced in 2022 (Schnepf et al 2013), of which 16 billion gallons are to be from cellulosic feedstocks. Starting from 2015, this same act requires a minimum of 3 billion gallons per year of ethanol to be produced from cellulosic feedstock (Schnepf et al 2013). The EISA went even further in defining Congressional goals and required that the biomass material should replace petroleum use for 30% by 2030 (USDA Biofuels Strategic Production Report 2010). In other words the supply of biomass produced should be one billion tons on a yearly basis. Perlack et al (2005) conducted the research to estimate feasibility of that supply with given land resources and potential technological change in conventional crops and perennial bioenergy crops. Their findings are that agricultural lands (cropland, idle cropland, and crop land pasture) can provide nearly 1 billion dry tons of sustainably collectable biomass and still continue to meet food, feed and export demands (Perlack et al, 2005).

Cellulosic feedstock has a great potential for large scale sustainable biofuel production. Some studies indicated that cellulosic feedstock provides high biomass because any part of the plant can be used for ethanol production. Estimates from the research conducted in World Watch Institute suggest that replacing gasoline with cellulosic ethanol could reduce greenhouse gas emissions by 86-94 percent, compared to 20 percent in the case of corn ethanol (World Watch Issue Brief, 2009). The same research indicated that some perennial crops may store enough carbon in the soil and root mass to overcompensate for carbon released during the rest of the lifecycle, meaning they could help take carbon dioxide out of the air on a net basis (World Watch Issue Brief, 2009).

The purpose of this study is to estimate the supply of hay in the US Midwest as it is important information for the study of feasibility of cellulosic ethanol production. Although studies have shown (Perlack et al, 2005) that it is technically feasible to supply one billion of agricultural biomass annually, there is need to exam economical feasibility. Economical feasibility will depend on the price offered for agricultural producers to harvest and deliver biomass and the financial incentive to reallocate land from conventional crop production to perennial grasses (Khanna et al, 2010). Particularly, we are interested in the supply response of grass hay in Midwestern U.S. to approximate how willing are the farmers to reallocate their land from traditionally produced crops in this area, such as corn, soybean and alfalfa, to the production of switchgrass or other grass hay to be used in ethanol production. Our interest is the supply of grassy feedstocks in general that would support ethanol production but we focus analysis on grass hay because here we have some empirical evidence about how farmers respond to prices in producing these crops.

2. Background and Justification

While many budgeting studies have estimated the cost of producing biomass from various grasses suitable for cellulosic ethanol production, the supply system for grass hay has not been evaluated as an estimate of the cost of producing biomass from such traditional grasses as switchgrass.

Gallagher and Johnson (1999) examined market effects for fuels, specifically ethanol which can be produced from agricultural/cellulose materials. From cost analysis conducted they concluded that corn residue-based production could be competitive with petroleum based gasoline. Results suggested that adoption of the new ethanol processing technology would reduce U.S. petroleum prices by 6 percent yielding a net annual welfare gain to the U.S. economy of $3.2 billion.

Khanna et al (2010) used nonlinear mathematical programming model, BEPAM (Biofuel and Environmental Policy Analysis Model) to estimate the quantity of agricultural biomass that would be produced at various prices. They look at two different types of land, cropland and idle/pasture land and feedstocks such as switchgrass, miscantus. The authors concluded that at price of $140/MT with given technology, yields and land availability, 18 M ha of idle cropland or cropland pasture would be used for perennial grasses. Miscanthus has the potential to provide 50% to 70% of the total biomass across the various scenarios and prices considered.

Du, Hennessy, and Edwards (2008) analyzed the impact of biofuel production on cash rents for Iowa farmland under hay and pasture. They were investigating the relationship between cash rental land rates and allocation of land. The authors found that cash rental rates for hay and pastureland would increase due to high corn prices and increased demand for crop land. Additionally they noted that if non crop ("low grade") land is used to produce feedstocks for cellulosic ethanol production that would reduce the pressure on prime farmland rates. However the authors concluded that the long run equilibrium impact of ethanol production on lower grade land is uncertain.

Many previous studies have estimated area elasticities and agricultural crop supply responses that are derived from consistent theoretical framework, i.e. using duality theory (Coyle 1993, Arnade and Kelch, 2007; Villezca-Becerra and Shumway, 1992; Chambers and Just, 1989; Ball, 1988; Morzuch et al, 1980).

Modeling crop production decisions in terms of acreage responses rather than in terms of output quantity responses was always more used because acreage responses may provide a closer proxy to actual intention to produce than ultimate production because it is not affected by weather (Coyle 1993). Many acreage response studies were conducted using Nerlove partial adjustment model and various extensions of the model (Askari and Cummings, 1977) but only a few studies addressed system of multiple crops. Coyle (1993) improved these models by integrating acreage demands into an economic model of production. He applied a duality theory approach to specify a system of output supplies and factor demands. He noted that a dual system approach has advantages compared to estimation of single output supply. First, it allows incorporation of contemporaneous covariance of error terms across equations to improve efficiency. Second, it allows specification of symmetry and reciprocity restrictions on coefficients across equations that are derived from profit maximization or cost minimization theory. Finally, the dual system approach permits recovery of the underlying technology.

Arnade and Kelch (2007) used a duality framework, where they estimated shadow price equations of area allocation derived from a profit function that represents Iowa agricultural producers. Further they were able to calculate individual crop area elasticities. Estimating shadow price equations jointly with a system of output supply and input demand equations allowed them to derive individual crop area response and output response to a change in prices. Hay supply elasticity was imbedded in the system of output supply, along with corn, soybeans, and other grains. They found that if the area of land to be allocated is held fixed, a 10% rise in hay price increases hay acreage by 2.13%.

Shumway (1983) examined the structure of agricultural production for six field crops (cotton, grain sorghum, wheat, corn, rice, hay) using a dual approach. Among others, their findings suggest that own price elasticity of hay supply for the year 1979 in U.S. was inelastic (0.1) and cross price elasticity between hay supply and corn price was also inelastic (-0.16).

A more recent study conducted by Megeressa (2013) examined changes in land allocation and cropping pattern needed to meet growing demand for ethanol. He applied duality theory with a quadratic profit function specification to examine the effect of price changes on acreage allocation in Nebraska. Crops that were considered are corn, wheat, soybeans, alfalfa, hay and all other crops. Megeressa examined three different categories of land: rain-fed lands, irrigated lands and total lands because farmers who own different qualities of land may respond differently to crop price changes. Results from this study showed that all own and cross price acreage responses are inelastic, which suggests that in the short run producers' acreage allocations are not very responsive to price changes. Estimated coefficients in the hay acreage equation indicated that increase in price of wheat, soybeans and alfalfa would reduce the acreage allocated to hay and pasture. Results indicate that a 20% increase in grass hay price can be expected to increase grass hay acreage by 4%, at the cost of acreage allocated to wheat and alfalfa. Estimated own price elasticity for hay acreage is 0.0241 and estimated cross-price elasticities for corn, wheat, soybeans, alfalfa are respectively 0.039, -0.017, -0.0048, -0.0259.

3. Theoretical Framework

In this study we will closely follow Coyle's (1993) work. Consider a farm producer who produces m outputs using a fixed amount of land $\bar{l}$. Assume that the producer is maximizing profit. His decision problem can be illustrated as follows:

$$(1) \quad \underset{(y,x,l)\varepsilon T(K)}{max} \{\sum_{j=1}^{m} p^j y^j - \sum_{i=1}^{n} w^i x^i = \pi\,(p, w, K, \bar{l}\,); s.t. \sum_{j=1}^{m} l^j \leq \bar{l}\,\}$$

Where: p^j is the price of crop j; y^j is the produced quantity of crop j; w^i is the price of input i; x^i is the quantity of the variable input used in the production of crop i; $\bar{l}$ is total farm land where l^j is land allocated to production of the crop j; K is a vector of other not allocated exogenous factors including fixed inputs; $\pi(p, w, K, \bar{l})$ is the producers dual profit function defined in (1), T(K) defines the set of choice variables allowed by the technology given K.

If we assume that input prices are constant, then all inputs may be considered fixed, and the profit function defined as the maximum of equation (1) becomes a revenue function, $R(p, K, \bar{l})$. Our study will consider two different functional forms to represent this revenue function. First, the normalized quadratic revenue function:

$$(2) \qquad \mathrm{R(p,K,l)} = \alpha + \sum_{i}^{4} \beta_i \frac{p^i}{p^n} + \frac{1}{2}\sum_{i,j}^{6} \beta_{ij} \frac{p^i}{p^n}\frac{p^j}{p^n} + \sum_{i,m}^{10} \beta_{\mathrm{i,m}} \frac{p^i}{p^n} l^m + \sum_{m}^{5} \beta_m l^m + \theta t$$

$$+ \frac{1}{2}\varphi \frac{p_i}{p_n} t^2 + \sum_{m}^{5} \rho_{\mathrm{m}}\, t l^m + \sum_{i}^{4} \delta_{i,t} \frac{p^i}{p^n} t + \varepsilon \qquad\qquad \sum_{m} l^m = \bar{l}$$

Second, the translog revenue function:

$$(3) \qquad \ln R(p, K, l) = \ln \alpha + \sum_{i}^{5} \beta_i \ln p^i + \sum_{m}^{5} \beta_m \ln l^m + \frac{1}{2}\sum_{i,j}^{10} \beta_{ij} \ln p^i \ln p^j$$

$$+ \frac{1}{2}\sum_{m,n}^{10} \gamma_{m,n} \ln l^m \ln l^n + \sum_{i,m}^{10} \delta_{im} \ln p^i \ln l^m + \theta t + \frac{1}{2}\varphi ln p^i t^2$$

$$+ \sum_{m}^{5} \rho_{\mathrm{m}}\, t l^m + \sum_{i}^{5} \delta_{i,t} p^i t + \varepsilon \qquad\qquad \sum_{m} l^m = \bar{l}$$

In the literature, crop acreage demands are specified in various ways. Coyle (1993) addressed the connections between acreage demands and behavioral principles by discussing assumptions considered necessary for specifying system of crop acreage demands, namely separability between enterprises, adding up and reciprocity restrictions. Following Hotelling's lemma, output choices are obtained by differentiating the revenue function with respect to the appropriate price. But again following Coyle, in this study we represent this optimal level as the acres allocated to that crop rather than the quantity ultimately produced. Differentiating equation (2) with respect to each crop price, solving the last for $\bar{l}$, a set of M-1 acreage equations can be obtained (Megeressa, p. 48):

$$(4) \qquad l_t^i = \beta_i + \sum_{j=1}^{4} \beta_{ij} p_{t-1}^j + \beta_{i5}\bar{l} + \beta_{i6} t + \sum_{s=1}^{11} \beta_{is} D_s + e_t^i$$

$$i = 1,2,3,4; \; s = 1, \dots 11$$

where $p_{t-1}=(p^1, p^2, p^3, p^4)$ is a vector of one-year lagged crop output prices, $\bar{l}$ is total crop acreage, t is time trend and D_s are dummy variables for s states; i=1,2,3,4 refers to corn, soybeans, alfalfa and other hay, respectively. The β's in (4) are not the same as the β's in equation (2), but can be expressed in terms of the originals, though we have no reason to identify those in equation (2). Adding a time trend to each equation allows for changes in acreage allocation through time caused by technological change, rather than price change.

Alternatively, we differentiate equation (3) with respect to price of crop i to obtain the optimal share of each crop in total production value:

$$(5) \qquad \frac{\partial lnR}{\partial lnp^i} = \frac{p^j y^j}{R} \quad = \beta_i + \sum_j b_{ij} \frac{p_j}{p_n} + b_{i,m}\bar{l} + d_i t + \sum_{s=1}^{11} \beta_{is} D_s + e_t^i$$

Revenue shares are derived by specifying the revenue equation as having the translog form (3) with respect to the logarithm of price of output p^j. Mathematically

$$(6) \qquad \frac{\partial lnR}{\partial lnp^j} = \frac{p^j}{R} \frac{\partial R}{\partial p^j} = \frac{p^j y^j}{R} = Rsh^j$$

where $Rsh^j = p^j y^j / R$ represents share of crop j in total revenues, p^j is crop output price, y^j is produced quantity of crop j, R is total revenue from crops under consideration. Similarly to the process for deriving equation (4), a linear system of M-1 crop revenue shares was derived as

$$(7) \qquad Rsh_t^i = \beta_i + \sum_{j=1}^{4} \beta_{ij} lnp_{t-1}^j + \beta_{i5} ln\bar{l} + \beta_{i6} t + \sum_{s=1}^{11} \beta_{is} D_s + e_t^i$$

$$i = 1,2,3,4; \ s = 1, \dots 11$$

Alternatively Coyle (1993) shows the derivation of acreage share equations. Acreage share equations are obtained by differentiating equation (3) with respect to the logarithm of crop acreage l_j.

$$(8) \qquad Ash_t^i = \beta_i + \sum_{j=1}^{4} \beta_{ij} p_{t-1}^j + \beta_{i5} ln\bar{l} + \beta_{i6} t + \sum_{s=1}^{11} \beta_{is} D_s + e_t^i$$

$$i = 1,2,3,4; \ s = 1, \dots 11$$

where $Ash_t^i = l_j / \bar{l}$. The reader will note that the β's in estimation equations (4), (7) and (8) are generic representations, and not intended to be equal across the equations.

Specific to multiple equations in time series data is the correlation between the error terms within the same year. Zellner (1962) demonstrated that the Seemingly Unrelated Regression (SUR) method can be used to account for this correlation and give more efficient parameter estimates. Accordingly, a system of four equations for corn, soybeans, alfalfa and other hay were fitted using the SUR estimation procedure. We fitted three separate specifications of these systems of equations, one for acreage response (eq. 4), another for revenue shares (eq. 7) and third for acreage shares (eq. 8). Additionally these three systems were fitted using Three-Stage Least Squares procedure (3SLS) which provides consistent and asymptotically efficient estimates. Following Coyle (1993), one-year lagged areas are used as instrumental variables for current areas. To satisfy economic theories, symmetry and homogeneity restrictions were imposed. Crop acreage, acreage share and revenue share elasticities were computed from the estimated parameters.

Crop acreage elasticities are calculated using equations (9):

$$(9)\quad \mu_{ij} = \frac{\%\ change\ in\ crop\ i\ acreage}{\%\ change\ in\ crop\ j\ price} = \frac{\partial\ acreage\ of\ crop\ i}{\partial price\ crop\ j}\ x\ \frac{average\ price\ crop\ j}{average\ acre\ i}$$

Formulas for the own and cross price elasticities corresponding to revenue share are presented with equations (10) and (11) (derivations are outlined in Appendix E):

$$(10)\ \eta_{ii} = \frac{\beta_{ii}}{average\ share_i} + average\ share_i - 1 \quad \text{own price elasticity}$$

$$(11)\ \eta_{ij} = \frac{\beta_{ij}}{average\ share_i} + average\ share_j \quad cross\ price\ elasticity$$

Acreage share elasticities are computed using formula (12) (derivation in Appendix E):

$$(12)\qquad \eta_{ij} = \frac{\beta_{ij} * p_j}{average\ acreage\ share_i}$$

4. Data

For the study, we considered four main crops and all other crops were aggregated. The main crops are corn, soybean, alfalfa and other hay. "Other hay" we take to be representative of grass hay such as switchgrass, though in fact we have no evidence regarding the fractions represented by other legumes versus grasses. We used 25 years of data, 1988 to 2012, for twelve states in Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin). Price received, acres harvested, total crop acres, quantity and value of production for the crops under consideration were obtained from National Agricultural Statistical Service (NASS) and all data is annual.

Acres harvested for "other" crops represents the difference between total acres harvested and summed acreages of four main crops (corn, soybean, alfalfa, other hay). Value of production of other crops in the same manner is a difference between total crop revenues (crop value of production) and value of production of the four main crops. Since production of all crops that are in the group “other crops” is measured in different units, we considered that the appropriate measure of output is revenue per acre. Therefore we divide value of production of other crops with acres of other crops to get revenue per acre. However, for corn, soybean, alfalfa and other hay, the prices of the crops were reported by NASS[1]. Depending on system of equations (explained in previous section) used, prices of all crops under consideration were expressed differently. The systems of acreage allocation and acreage share equations were estimated using either the level of current prices (3SLS) or one-year lagged prices (SUR and 3SLS). The system of revenue share equations was estimated using logarithm of prices (3SLS) or one-year lagged logarithms of prices (3SLS). Additionally, all systems mentioned were run using prices normalized by corn price.

The statistics of these data are presented in Table 1, with major trends for "other hay" depicted in Figures 1,2 and 3.

[1] Coyle (1993) compared results of two models that were using revenue per acre and crop prices and found similar results, with a minor difference in the level of significance of the explanatory variables

Table 1. Summary statistics of the variables

Item	Mean	Std.Dev.	Min	Max
CORN				
Acres harvested				
ILLINOIS	11,300,000	824,403.2	9,860,000	13,200,000
INDIANA	5,697,200	295,487.2	5,150,000	6,480,000
IOWA	12,600,000	758,390.2	11,300,000	14,200,000
KANSAS	2,925,600	1,002,595.0	1,245,000	4,790,000
MICHIGAN	2,359,600	167,667.3	2,050,000	2,635,000
MINNESOTA	7,079,200	746,741.1	5,375,000	8,680,000
MISSOURI	2,652,400	445,797.8	1,550,000	3,520,000
NEBRASKA	8,373,200	685,223.3	6,845,000	9,760,000
NORTH DAKOTA	1,323,200	748,309.0	675,000	3,560,000
OHIO	3,419,600	225,175.5	2,960,000	3,850,000
SOUTH DAKOTA	4,059,000	724,453.8	2,770,000	5,900,000
WISCONSIN	3,712,360	223,103.3	3,300,000	4,280,000
Total acres harvested	5,461,513	3,559,769.0	675,000	14,200,000
Production (bu)	710,000,000	571,000,000.0	16,400,000	2,420,000,000
Price ($/bu)	2.94	1.35	1.54	7.34
SOYBEANS				
Acres harvested				
ILLINOIS	9,565,200	675,118.0	8,280,000	10,600,000
INDIANA	5,127,200	478,404.6	4,180,000	5,770,000
IOWA	9,490,400	934,574.2	7,900,000	10,900,000
KANSAS	2,618,800	686,502.7	1,850,000	4,250,000
MICHIGAN	1,754,000	317,201.3	1,080,000	2,130,000
MINNESOTA	6,377,200	913,899.7	4,600,000	7,450,000
MISSOURI	4,748,000	449,295.7	3,600,000	5,350,000
NEBRASKA	3,862,200	1,029,618.0	2,360,000	5,100,000
NORTH DAKOTA	2,126,200	1,434,026.0	495,000	4,730,000
OHIO	4,278,800	342,689.4	3,480,000	4,720,000
SOUTH DAKOTA	3,334,000	990,101.0	1,730,000	4,720,000
WISCONSIN	1,180,800	472,536.8	390,000	1,700,000
Total acres harvested	4,538,567	2,763,965.0	390,000	10,900,000
Production (bu)	183,000,000	131,000,000.0	8,970,000	525,000,000
Price ($/bu)	7.10	2.60	4.05	14.70
ALFALFA				
Acres harvested				
ILLINOIS	519,000	167,667.8	280,000	950,000
INDIANA	350,800	50,097.4	280,000	460,000
IOWA	1,301,600	348,181.9	730,000	2,400,000
KANSAS	840,000	103,077.6	650,000	1,000,000
MICHIGAN	935,200	185,340.2	660,000	1,300,000
MINNESOTA	1,450,000	284,312.0	850,000	2,400,000

MISSOURI	415,200	93,234.5	240,000	600,000
NEBRASKA	1,256,400	217,540.8	770,000	1,500,000
NORTH DAKOTA	1,489,600	175,771.6	1,000,000	1,780,000
OHIO	570,000	122,873.6	350,000	725,000
SOUTH DAKOTA	2,330,000	264,181.1	1,800,000	3,000,000
WISCONSIN	1,956,000	592,544.0	1,050,000	3,100,000
Total acres harvested	1,117,817	652,576.6	240,000	3,100,000
Production (ton)	3,239,677	1,622,986.0	494,000	8,400,000
Price ($/ton)	96.85	37.59	39.00	234.00
OTHER HAY				
Acres harvested				
ILLINOIS	339,800	74,812.0	240,000	550,000
INDIANA	329,400	44,961.1	280,000	480,000
IOWA	390,400	109,942.4	270,000	800,000
KANSAS	1,904,000	253,278.5	1,550,000	2,400,000
MICHIGAN	298,800	79,860.3	200,000	600,000
MINNESOTA	782,000	189,098.7	600,000	1,600,000
MISSOURI	3,465,600	314,974.6	3,000,000	3,950,000
NEBRASKA	1,798,000	182,847.8	1,550,000	2,200,000
NORTH DAKOTA	1,380,800	317,699.0	900,000	2,100,000
OHIO	689,600	95,633.0	500,000	900,000
SOUTH DAKOTA	1,602,000	204,368.9	1,200,000	2,000,000
WISCONSIN	437,600	84,522.2	300,000	680,000
Total acres harvested	1,118,167	936,219	200,000	3,950,000
Production (ton)	1,862,780	1,542,788	400,000	7,900,000
Price ($/ton)	66.17	23.29	23.50	185.00
OTHER CROPS				
Acres harvested				
ILLINOIS	1,218,040	457,293.5	365,000	2,229,000
INDIANA	573,240	209,319.2	238,000	1,055,000
IOWA	260,000	198,704.3	66,000	827,000
KANSAS	12,900,000	1,385,114.0	10,200,000	15,000,000
MICHIGAN	1,179,360	163,709.6	918,000	1,570,000
MINNESOTA	3,543,360	891,623.4	2,325,000	5,135,000
MISSOURI	1,908,800	523,915.2	892,000	2,905,000
NEBRASKA	3,012,800	850,148.2	1,686,000	4,409,000
NORTH DAKOTA	14,100,000	2,049,776.0	9,118,000	17,600,000
OHIO	1,120,720	247,304.7	499,000	1,542,000
SOUTH DAKOTA	4,398,760	917,598.3	2,489,000	6,033,000
WISCONSIN	656,240	164,851.8	459,000	1,050,000
Total acres harvested	3,743,870	4,634,230.0	66,000	17,600,000
Production ($)	739,000,000	821,000,000.0	13,030,000	5,430,000,000
Price ($)	270.98	166.30	60.41	1083.92

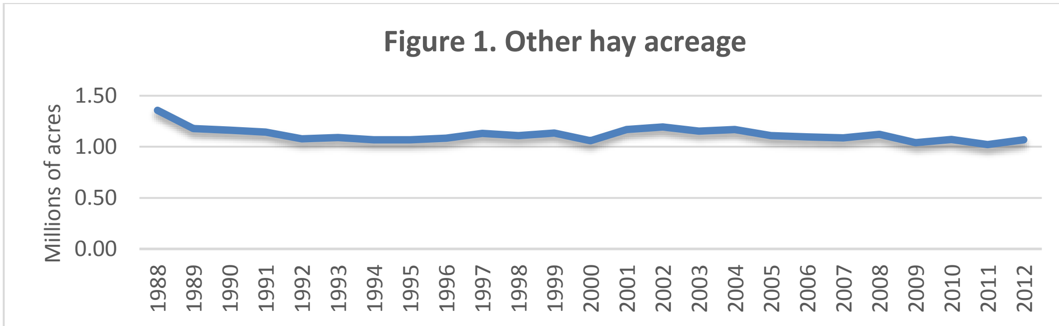


Figure 1. Other hay acreage
Millions of acres
1.50
1.00
0.50
0.00
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

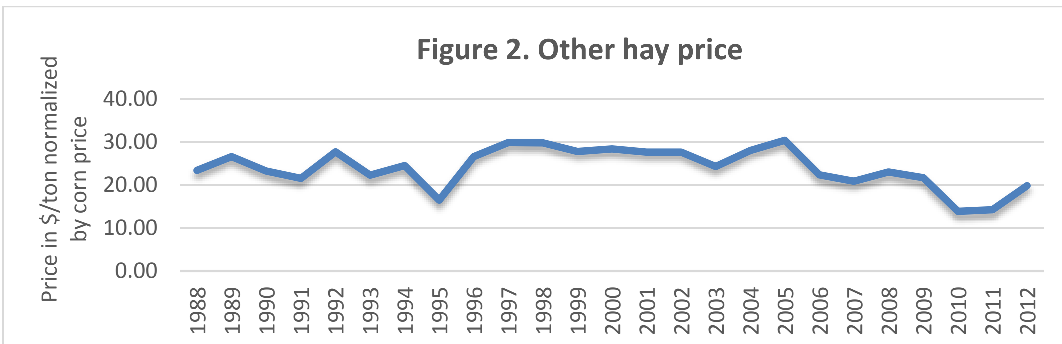


Figure 2. Other hay price
Price in $/ton normalized by corn price
40.00
30.00
20.00
10.00
0.00
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

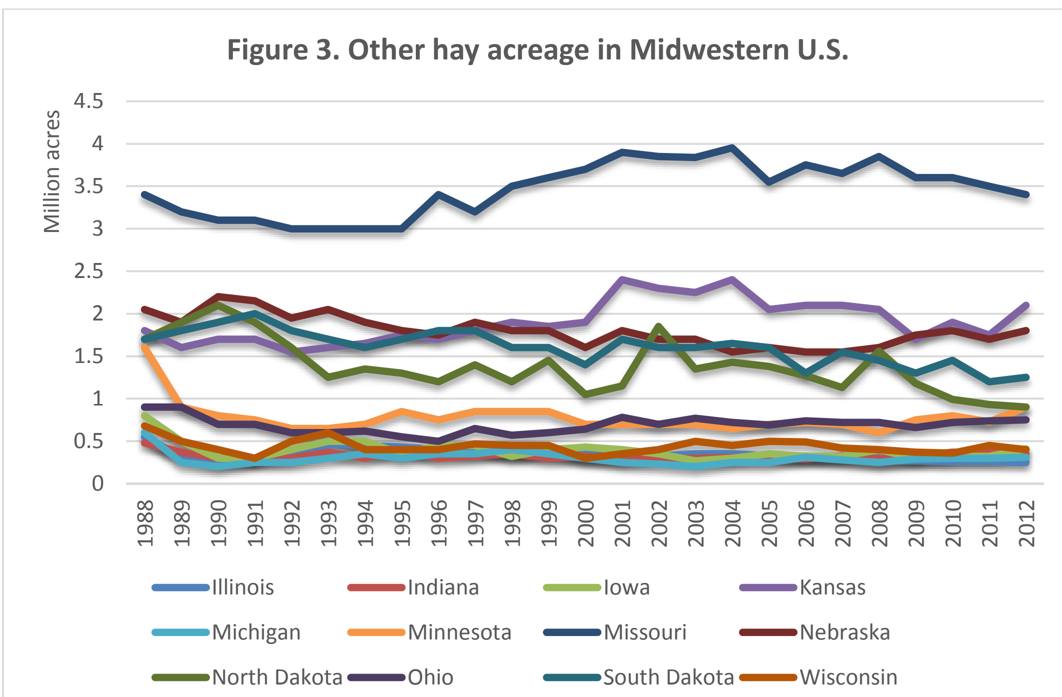


Figure 3. Other hay acreage in Midwestern U.S.
Million acres
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012
Illinois
Indiana
Iowa
Kansas
Michigan
Minnesota
Missouri
Nebraska
North Dakota
Ohio
South Dakota
Wisconsin

4.1.Results and Discussion

In general, economic theory suggests that supply of outputs (crops) is positively sloped. An increase in own price is expected to increase quantity produced. In our three cases that would result in more acres devoted to production, an increase in acreage share or an increase in revenue share, respectively. If the price of competing crops increases, a negative effect on acreage is expected. However, not all estimates from our acreage regressions run have the expected signs, except for corn in SUR and 3SLS-lagged prices approaches. Statistically significant estimates in some cases show that an increase in own price will result in decrease in acreage, which contradicts expectations. Estimates for the first model, acreage equations, are presented in Table A1 (Appendix A) for estimations using level prices, and Table B1 (Appendix B) for estimations using crop prices normalized by corn price.

The 3SLS models used both current prices and prices lagged for one year. The economic reasoning is that lagged prices represent adaptive price expectations that arise to reflect the gap between planting decisions and the time when crop is harvested (Arnade and Cooper, 2013). Besides lagged prices, other forms of price expectations have been used such as naïve expectations (Shumway and Chang, 1980) and futures prices (Gardner, 1976).

The total number of estimated parameters is 216 in each of three systems, acreage, acreage share, and revenue share (Table A1, Table A2 and Table A3 in Appendix A), 124 of which are significant at the 5% level in first, 127 in the second and 118 in the third system of equations. The number of observations in the models was 288 and the number of regressors is 17.

4.1.1 System of Acreage Allocation Equations

None of the specifications of the system of acreage allocations satisfy the regularity conditions of a well-behaved technology, such as concavity or homogeneity. The "other hay" acreage equation yielded negative own-price coefficients, and unexpectedly positive cross-price coefficients for prices of corn and alfalfa, the latter being significantly different from zero (Table A1). We conclude that the system of acreage allocation decisions doesn’t provide a satisfactory explanation of what affects changes in acres of other hay.

In Appendix B we present results of the specifications of the acreage allocation system when prices are normalized by corn price, rather than other crops price as was implicit in the specifications described in the above paragraph. Results (Appendix B-Table B1) again yielded negative own-price coefficient for other hay, but here the coefficient of response of other hay to alfalfa price was again positive and statistically significant, while response coefficients for soybean price remained insignificant. Corresponding elasticities are shown in Appendix D (Table D1).

4.1.2 System of Acreage Share Equations

The system of acreage share equations (from equation (8), results in Table A2) provided estimates that are very similar to the acreage allocation system just discussed. In the other hay acreage equation, whether prices are lagged or not, own price coefficient is negative, corn and alfalfa prices have positive rather than negative coefficients, and only soybean price coefficients have the expected negative sign, but are insignificant. Corresponding elasticities are shown in Table C2. When we estimated these specifications with prices normalized by corn prices (Appendix B- Table B2), own-price response of other hay is again negative, response to soybean price remains positive but becomes significant, and response to corn price remains negative. Corresponding elasticities are shown in Table D2 (Appendix D). Given these results, we conclude that the system of acreage share equations, as we have been able to estimate it, does not provide a satisfactory explanation of changes in the acreage of other hay.

4.1.3 System of Revenue Share Equations

The estimated system of revenue share equations as specified in equation (7) are shown in Table A3. In the other hay share equation, own-price coefficient is positive and significant, while coefficients of competing crops are all negative as expected, and significant for alfalfa and soybeans, though not for corn. Converted to elasticities (see below), the estimated response of other hay share to own price is 0.78, with negative responses to soybean and alfalfa prices, but positive responses to corn and other crop prices. The own-price response obtained from this specification is plausible (Table C3), but confidence in the own-price estimate is weakened by the poor characteristics of the estimated system as a whole (own-price responses of each of the other crops is negative, causing us to reject the plausibility of the estimates of the system as a whole).

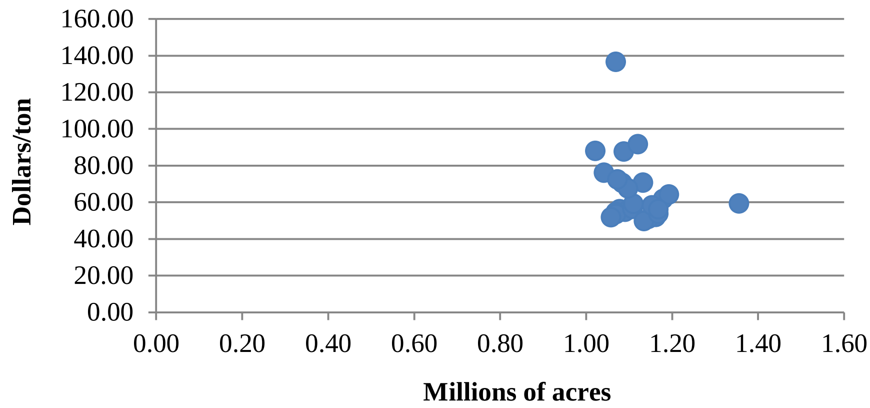
The elasticities can be obtained by differentiation of the share equations, where elasticities are function of estimated parameters and average shares (as shown in Appendix E). Table C3 shows own and cross price elasticities calculated in this manner from the Table A3 parameter estimates evaluated at the average value of shares. (Note that elasticities do not always take the same sign as the coefficient estimated in the share equation). Price elasticity for hay was the only positive own price elasticity (0.78) as expected. This result would mean that increase in other hay price of 10% would increase acreage devoted to production of other hay by 7.8%. However such a conclusion can't be inferred since the other hay equation was part of a system of equations that resulted in negative own price elasticities for corn, soybeans, alfalfa and other crops.

4.1.4 Discussion

We have attempted to estimate the factors affecting the acreage of "other hay" in the context of a system of equations explaining allocations among all crops. For each of the three basic models (acreage allocation equations, acreage share equations and revenue share equations), we have estimated with seemingly unrelated regression (SUR) and three-stage least squares (3SLS), using both current and lagged prices, and with prices normalized alternatively with other crop prices and with corn price. We have concluded that none of alternative systems, as we have estimated them, result in reasonable estimates of factors affecting other hay acreage. Therefore the conclusion we draw is that the production of other hay in this region has not been significantly affected by prices.

To support this conclusion, the relationship between acreage and prices of other hay in the region is illustrated on the Graph 4. It is apparent that there is no simple positive relationship between the two. For prices ranging from $40/ton to $100/ton, acreage is concentrated at around 1.1 million acres.

Graph 4. Relationship between acreage and price of other hay



A summary of results of the 3SLS-lagged price regressions with regard to implications for hay response is presented in Table 2.

Table 2. What affects supply of hay (based on 3SLS-lagged prices models)?

Variables	Acreage equations	Acreage share equations	Revenue share equations
		Hay response elasticities	
Corn price	-0.0016	-0.0048	0.0298
Soybeans price	0.0016	0.0090	-0.4311
Alfalfa price	0.3540	0.3584	-2.0175
Other hay price	-0.2068	-0.1983	2.9317
Other crops price	-0.0565	-0.0776	-0.5130

Estimates of other hay supply that proved to be most consistent with economic theory are system of revenue share equations estimates. Other hay own price elasticity is positive (2.93) (Table 2). Cross price elasticities show (Table 2) that prices of competing crops, alfalfa and all other crops affect supply of hay significantly in a manner that complies with theory (price of competing crops has reverse effect on hay supply). Price of soybeans has also reverse effect on hay supply although estimate is insignificant. However, parameters of other equations in that system are totally implausible, casting doubt on the reliability of coefficients estimated for the hay supply equation.

An alternative approach we used is specifying profit shares instead of revenue shares, where inputs were tested for significance in explaining responsiveness of other hay acres. Total land, capital and self-employed and unpaid family labor were considered to be fixed inputs and total intermediate input is variable input. Estimation of this system of equations defined in this manner gave similar results to those reported in this study.

5. Conclusions

This study examined supply of hay excluding alfalfa, based on the assumption that "other hay" is similar to species that might be grown as cellulosic feedstock. The area under consideration constituted 12 states in the upper Midwestern U.S. The study considered acreage and production of corn, soybean, alfalfa and "other hay" (hay excluding alfalfa), and "all other crops". Data required for the study was gathered from National Agricultural Statistical Service (NASS) for the period covering 1988 to 2012. We specified three different models of simultaneous supply equations to obtain the best estimate possible for hay supply, specifically an acreage allocation system, an acreage share system, and a revenue share system. Each system was estimated using SUR and 3SLS estimation procedures. Three stage least squares were run alternatively with current and lagged level prices. We also normalized prices alternatively by corn price and by an index of other crop prices. Estimates for the omitted equations were recovered using symmetry and homogeneity restrictions. Crop acreage elasticities were computed from the estimated parameters.

Based on standard economic and econometric interpretations we were not able to robustly estimate the system of supply equations using any of the various specifications. It is not clear what economic models or econometric methods might be used next, to come closer to satisfying the conditions of well-behaved technology, such as convexity and monotonicity. However, this requires more research at a higher level than this study warrants. Additionally, there is possibility of specification error and the model we are using does not represent reality as the data shows. Hay is usually produced for on-farm use and only supplied in the market as the marketed surplus, once the internal use is satisfied, and that can't be captured with this model.

Because we were not able to estimate a robust estimate of supply response for "other hay", we conclude that the quantity of hay produced has not been significantly and consistently affected by prices.

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APPENDIX A

Table A1. Estimates for acreage equations							
Parameters		SUR		3SLS-lagged prices		3SLS-current prices	
		Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
corn	p_{corn} lag	282085.7	4.49	261650.1	3.86	-4243.784	-0.04
	$p_{soybeans}$lag	-33594.23	-1.03	-23804.89	-0.66	97009.84	2.17
	$P_{alfalfa}$lag	-7111.578	-3.13	-6621.243	-2.89	-1495.029	-0.59
	$P_{other\ hay}$lag	3704.039	1.16	2797.228	0.82	1535.13	0.54
	land	0.3135712	8.05	0.4205402	1.67	0.4127204	1.39
	t	38040.14	8.69	35641.72	5.16	21705.29	2.31
	dum1	2973841	4.98	1365048	0.36	1390237	0.31
	dum2	794089.7	3.96	350111.4	0.34	250871.4	0.21
	dum3	3934672	6.15	2203764	0.54	2268045	0.47
	dum4	-4917018	-9.24	-6346456	-1.89	-6256673	-1.58
	dum5	-916677.9	-7.11	-757522.3	-1.97	-797638.8	-1.84
	dum6	-66401.32	-0.15	-1281761	-0.45	-1253379	-0.38
	dum7	-2544248	-10.62	-3119552	-2.34	-3209167	-2.09
	dum8	1334681	3.16	225059.5	0.09	386585.8	0.12
	dum9	-6408951	-12.57	-7771530	-2.42	-7606454	-2.01
	dum10	-686368.7	-4.21	-929394.2	-1.68	-1162656	-1.96
	dum11	-2121317	-6.48	-2966450	-1.49	-2882273	-1.23
	_cons	546740.3	1.72	-266485.4	-0.14	-468235.7	-0.21
soybeans	p_{corn} lag	-33594.23	-1.03	-23804.89	-0.66	97009.84	2.17
	$p_{soybeans}$lag	-53694.65	-2.01	-48504.38	-1.65	-178825.1	-6.08
	$P_{alfalfa}$lag	-5052.588	-1.96	-5817.913	-2.1	422.5128	0.17
	$P_{other\ hay}$lag	-1769.084	-0.48	-1930.093	-0.48	-1027.266	-0.31
	land	0.3122086	6.13	0.7488995	2.17	0.1755268	0.76
	t	93196.45	16.36	82854.23	8.39	106579.4	12.01
	dum1	3826703	4.91	-2746209	-0.53	5796944	1.67
	dum2	2858583	10.93	1051328	0.73	3258085	3.39
	dum3	3357537	4.02	-3702366	-0.66	5524181	1.48
	dum4	-2693079	-3.87	-8535314	-1.85	-918207.1	-0.3
	dum5	1078675	6.44	1695281	3.22	828490.1	2.31
	dum6	1729095	2.91	-3211659	-0.82	3254109	1.24
	dum7	2071549	6.67	-216537.9	-0.12	2633522	2.17
	dum8	-618683.6	-1.12	-5189557	-1.44	873690	0.36
	dum9	-3136248	-4.71	-8694986	-1.97	-1278504	-0.43
	dum10	2728169	13.15	1821696	2.41	2732965	5.52
	dum11	-347728	-0.81	-3805701	-1.39	786804.1	0.43
	_cons	-1549818	-3.76	-4860145	-1.86	-621180	-0.35

alfalfa	p_{corn} lag	-7111.578	-3.13	-6621.243	-2.89	-1495.029	-0.59
	$p_{soybeans}$lag	-5052.588	-1.96	-5817.913	-2.1	422.5128	0.17
	$P_{alfalfa}$lag	-1755.921	-2.33	-2127.017	-2.41	-2658.131	-4.22
	$P_{other\ hay}$lag	2893.49	3.55	2964.779	3.51	1926.751	2.59
	land	0.0731654	4.03	0.3371771	2.44	0.2339682	3.09
	t	-19541.4	-9.86	-24909.16	-6.41	-20563.3	-7.21
	dum1	-2524722	-9.06	-6501552	-3.12	-4919080	-4.3
	dum2	-1876099	-20.18	-2973773	-5.13	-2502348	-7.77
	dum3	-1840523	-6.17	-6110537	-2.73	-4422765	-3.61
	dum4	-2048102	-8.24	-5581426	-3.01	-4184241	-4.12
	dum5	-917527.8	-15.82	-548041.2	-2.65	-672482.5	-5.62
	dum6	-1321744	-6.24	-4310233	-2.75	-3132224	-3.65
	dum7	-1842785	-16.72	-3228390	-4.41	-2657560	-6.58
	dum8	-1444309	-7.34	-4206656	-2.9	-3131673	-3.95
	dum9	-1322251	-5.58	-4680098	-2.66	-3396380	-3.53
	dum10	-1456065	-20.19	-2010298	-6.62	-1741618	-9.99
	dum11	-158493.7	-1.04	-2249392	-2.05	-1435549	-2.39
	_cons	1625495	11.09	-363606.3	-0.35	447654.2	0.77
other hay	p_{corn} lag	3704.039	1.16	2797.228	0.82	1535.13	0.54
	$p_{soybeans}$lag	-1769.084	-0.48	-1930.093	-0.48	-1027.266	-0.31
	$P_{alfalfa}$lag	2893.49	3.55	2964.779	3.51	1926.751	2.59
	$P_{other\ hay}$lag	-2688.405	-2.03	-2713.694	-1.93	-2381.148	-2.01
	land	0.0478451	2.79	0.0551571	0.53	0.2076144	2.72
	t	-6483.603	-3.52	-6656.134	-2.31	-8727.709	-3.04
	dum1	-828120.8	-3.15	-939260.5	-0.61	-3224758	-2.8
	dum2	-336747.2	-3.83	-368974.3	-0.86	-982027.8	-3.02
	dum3	-837887.4	-2.97	-956790.1	-0.57	-3417893	-2.76
	dum4	833541.3	3.55	735271.2	0.53	-1302996	-1.27
	dum5	-57537.66	-1.01	-47593.41	-0.3	171813.7	1.41
	dum6	-235154.3	-1.17	-318510	-0.27	-2041068	-2.35
	dum7	2715041	25.93	2674518	4.88	1891337	4.64
	dum8	899526.9	4.84	824125.5	0.77	-782949	-0.98
	dum9	352565.1	1.57	260670.3	0.2	-1690836	-1.74
	dum10	39512.64	0.58	20390.82	0.09	-260371.4	-1.48
	dum11	812644.6	5.64	755250.9	0.92	-459633.8	-0.76
	_cons	53515.42	0.39	-2898.633	0	-1120864	-1.92

Table A2. Estimates for acreage share equations

Parameters		SUR		3SLS-lagged prices		3SLS-current prices	
		Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
corn	p_{corn} lag	0.0181843	5.22	0.017733	4.77	0.0007863	0.12
	$p_{soybeans}$lag	-0.0026999	-1.48	-0.0024693	-1.24	0.0059136	2.36
	$P_{alfalfa}$lag	-0.0003364	-2.7	-0.0003254	-2.6	-0.0001827	-1.29
	$P_{other\ hay}$lag	0.0000969	0.56	0.0000711	0.38	0.0002251	1.43
	land	4.29E-09	2.03	7.59E-09	0.55	1.25E-08	0.76
	t	0.001949	8.2	0.0018777	5	0.0008283	1.6
	dum1	-0.0370015	-1.14	-0.0865292	-0.42	-0.1678963	-0.68
	dum2	-0.0096007	-0.88	-0.0232061	-0.41	-0.0521092	-0.77
	dum3	-0.0106	-0.31	-0.0639015	-0.29	-0.1480705	-0.56
	dum4	-0.3875995	-13.41	-0.4316408	-2.36	-0.4989032	-2.27
	dum5	-0.1002868	-14.3	-0.0953803	-4.55	-0.0927026	-3.86
	dum6	-0.1446585	-5.85	-0.1820682	-1.17	-0.2412596	-1.3
	dum7	-0.2838442	-21.8	-0.3014707	-4.15	-0.3315285	-3.89
	dum8	-0.0613227	-2.68	-0.0955774	-0.67	-0.144745	-0.84
	dum9	-0.4631006	-16.73	-0.505126	-2.89	-0.564002	-2.69
	dum10	-0.1255312	-14.15	-0.1328424	-4.41	-0.1538112	-4.68
	dum11	-0.2467973	-13.87	-0.2728563	-2.52	-0.3116574	-2.39
	_cons	0.4003085	23.2	0.3754118	3.63	0.3185783	2.59
soybeans	p_{corn} lag	-0.0026999	-1.48	-0.0024693	-1.24	0.0059136	2.36
	$p_{soybeans}$lag	-0.0038082	-2.56	-0.003814	-2.41	-0.0111209	-6.94
	$P_{alfalfa}$lag	-0.0001411	-0.96	-0.0001255	-0.84	0.0001309	0.97
	$P_{other\ hay}$lag	-0.0002492	-1.23	-0.0002674	-1.25	-0.0002014	-1.14
	land	2.53E-10	0.09	-3.75E-09	-0.22	-1.41E-08	-1.13
	t	0.0061106	19.98	0.0061713	12.81	0.0070795	14.99
	dum1	0.2674085	6.36	0.3278475	1.28	0.4798352	2.55
	dum2	0.281607	19.93	0.2983071	4.23	0.3331926	6.4
	dum3	0.2412194	5.35	0.3060561	1.11	0.4717837	2.33
	dum4	-0.0310677	-0.83	0.0225659	0.1	0.1584581	0.95
	dum5	0.12411	13.73	0.1186869	4.57	0.1011291	5.21
	dum6	0.1782594	5.56	0.2236066	1.16	0.3401733	2.4
	dum7	0.2109088	12.55	0.2316992	2.57	0.2785277	4.24
	dum8	0.0541238	1.82	0.0961796	0.54	0.2074505	1.58
	dum9	-0.0592407	-1.65	-0.0082955	-0.04	0.1297536	0.81
	dum10	0.2844194	25.08	0.2925588	7.86	0.3009813	11.21
	dum11	0.0540467	2.34	0.0858653	0.64	0.1706465	1.72
	_cons	0.1287017	5.79	0.1587859	1.24	0.232179	2.44

alfalfa	p_{corn} lag	-0.0003364	-2.7	-0.0003254	-2.6	-0.0001827	-1.29
	$p_{soybeans}$lag	-0.0001411	-0.96	-0.0001255	-0.84	0.0001309	0.97
	$P_{alfalfa}$lag	-0.0001101	-1.65	-0.0001541	-1.65	-0.0001645	-3.03
	$P_{other\ hay}$lag	0.0002016	3.79	0.0002129	3.86	0.0001297	2.6
	land	3.28E-09	1.85	3.36E-08	2.26	1.64E-08	2.28
	t	-0.0017824	-9.33	-0.0024144	-5.82	-0.0018887	-7.09
	dum1	-0.2685231	-9.89	-0.7249152	-3.23	-0.4636842	-4.28
	dum2	-0.2257028	-24.9	-0.3517039	-5.64	-0.2773429	-9.07
	dum3	-0.2408004	-8.28	-0.7308065	-3.03	-0.4511747	-3.88
	dum4	-0.2442081	-10.08	-0.6496628	-3.26	-0.4182311	-4.35
	dum5	-0.0965774	-17.22	-0.054222	-2.45	-0.0768763	-6.78
	dum6	-0.2029977	-9.83	-0.5459285	-3.24	-0.3504901	-4.3
	dum7	-0.2230825	-20.83	-0.3820623	-4.86	-0.289998	-7.58
	dum8	-0.2070041	-10.79	-0.5239957	-3.36	-0.3441028	-4.58
	dum9	-0.207133	-8.97	-0.5924146	-3.13	-0.3753909	-4.11
	dum10	-0.1883598	-26.89	-0.2519518	-7.74	-0.2126669	-12.84
	dum11	-0.1181168	-7.94	-0.3580408	-3.03	-0.2219699	-3.9
	_cons	0.237126	16.61	0.0084629	0.08	0.1415356	2.59
other hay	p_{corn} lag	0.0000969	0.56	0.0000711	0.38	0.0002251	1.43
	$p_{soybeans}$lag	-0.0002492	-1.23	-0.0002674	-1.25	-0.0002014	-1.14
	$P_{alfalfa}$lag	0.0002016	3.79	0.0002129	3.86	0.0001297	2.6
	$P_{other\ hay}$lag	-0.0001665	-2.06	-0.0001746	-2.04	-0.0001562	-2.08
	land	-1.96E-09	-1.97	-3.42E-09	-0.57	5.40E-09	1.27
	t	-0.0003643	-3.39	-0.0003385	-2.02	-0.0004328	-2.72
	dum1	-0.0110731	-0.73	0.010921	0.12	-0.1209126	-1.88
	dum2	-0.0217252	-4.26	-0.0157557	-0.63	-0.0505134	-2.78
	dum3	-0.0075937	-0.46	0.0160287	0.16	-0.1261811	-1.82
	dum4	0.0611613	4.49	0.0807135	1	-0.0371101	-0.65
	dum5	-0.0121305	-3.68	-0.0141352	-1.53	-0.0011858	-0.17
	dum6	0.0060225	0.52	0.0225311	0.33	-0.0769996	-1.59
	dum7	0.2134247	34.96	0.2208713	6.9	0.1761445	7.74
	dum8	0.0665795	6.17	0.082008	1.3	-0.0113345	-0.25
	dum9	0.0389398	2.99	0.0576105	0.75	-0.0557798	-1.03
	dum10	0.0097539	2.42	0.012467	0.93	-0.0025629	-0.26
	dum11	0.0644155	7.7	0.0760585	1.6	0.0055538	0.16
	_cons	0.0688297	8.56	0.0797999	1.76	0.0159589	0.49

Table A3. Estimates for revenue share equations

Parameter		SUR		3SLS-lagged prices		3SLS-current prices	
		Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
corn	$lnp_{corn}lag$	0.121103	8.39	0.119822	8.19	0.147322	7.83
	$lnp_{soybenas}lag$	-0.04945	-3.44	-0.04606	-3.12	-0.0605677	-3.62
	$lnp_{alfalfa}lag$	-0.03285	-3.89	-0.03927	-3.61	-0.0220476	-1.9
	$Lnp_{other\ hay}lag$	-0.00285	-0.59	-0.00144	-0.27	-0.0080721	-1.38
	lnland	0.080923	1.4	0.025338	0.12	-0.0147857	-0.06
	t	0.00391	11.14	0.004037	9.83	0.0028349	5.67
	dum1	-0.00203	-0.03	0.058178	0.25	0.0985634	0.41
	dum2	0.014414	0.54	0.039577	0.43	0.052603	0.55
	dum3	0.013608	0.21	0.076028	0.32	0.1200466	0.47
	dum4	-0.31784	-5.48	-0.26242	-1.22	-0.2240298	-0.99
	dum5	-0.11474	-7.71	-0.12515	-2.9	-0.1330074	-2.9
	dum6	-0.11992	-2.3	-0.07013	-0.36	-0.0346881	-0.17
	dum7	-0.24319	-7.82	-0.21299	-1.93	-0.1980526	-1.71
	dum8	0.027613	0.56	0.073176	0.4	0.1103622	0.57
	dum9	-0.48324	-8.59	-0.43149	-2.08	-0.3891641	-1.77
	dum10	-0.10069	-5.78	-0.08436	-1.6	-0.0824918	-1.54
	dum11	-0.20078	-4.88	-0.16306	-1.08	-0.1316064	-0.83
	_cons	-0.71596	-0.78	0.182679	0.05	0.7847632	0.22
soybean	$lnp_{corn}lag$	-0.04945	-3.44	-0.04606	-3.12	-0.0605677	-3.62
	$lnp_{soybenas}lag$	0.024287	1.36	0.018809	1.01	0.0309528	1.66
	$lnp_{alfalfa}lag$	0.005505	0.59	0.014421	1.2	-0.0030727	-0.29
	$Lnp_{other\ hay}lag$	-0.01615	-2.88	-0.01761	-2.83	-0.0190621	-3.24
	lnland	-0.08574	-1.56	-0.3244	-1.54	-0.1982102	-0.97
	t	0.004437	13.04	0.00459	11.47	0.0053785	11.42
	dum1	0.307119	5.19	0.560242	2.5	0.4298845	1.98
	dum2	0.267632	10.66	0.366813	4.11	0.3197308	3.71
	dum3	0.292718	4.74	0.557563	2.38	0.4197879	1.85
	dum4	0.07135	1.3	0.30682	1.47	0.1844044	0.91
	dum5	0.059205	4.18	0.012706	0.3	0.0393589	0.96
	dum6	0.212122	4.28	0.423478	2.26	0.3125565	1.73
	dum7	0.266102	9.02	0.385421	3.59	0.3267235	3.15
	dum8	0.130255	2.76	0.332643	1.87	0.2239963	1.29
	dum9	0.041927	0.78	0.272076	1.34	0.1455584	0.74
	dum10	0.259664	15.63	0.313422	6.15	0.2924985	6.02
	dum11	0.156525	4	0.322577	2.2	0.2331371	1.65
	_cons	1.495169	1.72	5.257792	1.58	3.318569	1.03

alfalfa	$lnp_{corn}lag$	-0.03285	-3.89	-0.03927	-3.61	-0.0220476	-1.9
	$lnp_{soybenas}lag$	0.005505	0.59	0.014421	1.2	-0.0030727	-0.29
	$lnp_{alfalfa}lag$	0.030293	2.96	0.020856	1.3	0.0326751	2.49
	$Lnp_{other\ hay}lag$	-0.01907	-3.18	-0.0231	-3.35	-0.0173819	-3.03
	lnland	0.094937	2.36	0.869212	3.74	0.6828077	3.38
	t	-0.00291	-11.51	-0.00358	-8.16	-0.0036326	-8.2
	dum1	-0.27523	-6.35	-1.09802	-4.44	-0.9033447	-4.21
	dum2	-0.205	-11.13	-0.52987	-5.39	-0.4565731	-5.41
	dum3	-0.25157	-5.56	-1.11179	-4.3	-0.906605	-4.05
	dum4	-0.21476	-5.33	-0.9794	-4.26	-0.7975037	-4
	dum5	-0.03248	-3.11	0.118655	2.56	0.0801752	1.97
	dum6	-0.20758	-5.72	-0.89434	-4.34	-0.7294933	-4.08
	dum7	-0.20866	-9.64	-0.60082	-5.09	-0.5104994	-5.01
	dum8	-0.21269	-6.14	-0.86563	-4.41	-0.707288	-4.13
	dum9	-0.24002	-6.11	-0.98376	-4.41	-0.8001099	-4.11
	dum10	-0.14178	-11.35	-0.32364	-5.78	-0.2861852	-6.1
	dum11	-0.1285	-4.48	-0.66518	-4.12	-0.534265	-3.81
	_cons	-1.30466	-2.05	-13.5478	-3.69	-10.64413	-3.35
other hay	$lnp_{corn}lag$	-0.00285	-0.59	-0.00144	-0.27	-0.0080721	-1.38
	$lnp_{soybenas}lag$	-0.01615	-2.88	-0.01761	-2.83	-0.0190621	-3.24
	$lnp_{alfalfa}lag$	-0.01907	-3.18	-0.0231	-3.35	-0.0173819	-3.03
	$lnp_{other\ hay}lag$	0.039622	6.98	0.043815	6.75	0.0447048	8.51
	lnland	-0.01906	-1.04	-0.04366	-0.6	-0.0201125	-0.28
	t	-0.00069	-5.87	-0.00065	-4.7	-0.0005487	-3.51
	dum1	-0.00096	-0.05	0.024984	0.33	-0.0011873	-0.02
	dum2	-0.00582	-0.7	0.004458	0.15	-0.0075382	-0.25
	dum3	0.002625	0.13	0.029916	0.37	0.0025313	0.03
	dum4	0.047369	2.59	0.071485	1	0.0476461	0.68
	dum5	-0.01181	-2.44	-0.01721	-1.18	-0.013723	-0.96
	dum6	0.009498	0.58	0.031548	0.49	0.0099003	0.16
	dum7	0.119991	12.15	0.133339	3.61	0.1203887	3.36
	dum8	0.015056	0.96	0.034925	0.57	0.0157242	0.26
	dum9	0.025863	1.45	0.04948	0.71	0.0286004	0.42
	dum10	0.020462	3.59	0.027314	1.55	0.0187204	1.13
	dum11	0.033485	2.57	0.050243	1	0.0336313	0.69
	_cons	0.291929	1.01	0.684579	0.6	0.2896437	0.26

APPENDIX B

Table B1. Estimates for acreage equations- prices normalized by corn price

Parameter		SUR		3SLS-LAGGED PRICES		3SLS-CURRENT PRICES	
		Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
soybeans	npsoy_t1	93406.27	1.05	64449.85	0.66	-153106.40	-0.96
	npalfa_t1	6126.05	3.19	6160.02	2.57	8554.40	1.73
	npoh_t1	6126.05	3.19	6160.02	2.57	8554.40	1.73
	npoc_t1	4271.08	3.01	6282.04	2.6	3123.65	1.24
	land	0.32	6.07	1.00	2.21	0.54	1
	t	65204.75	13.04	46721.25	3.33	62114.34	3.74
	dum1	3880105.00	4.84	-6241839.00	-0.93	438340.10	0.05
	dum2	2813050.00	10.17	90555.46	0.05	1762265.00	0.78
	dum3	3626141.00	4.21	-7174207.00	-1	-90480.70	-0.01
	dum4	-2327955.00	-3.23	-11200000.00	-1.9	-5445301.00	-0.75
	dum5	1010958.00	6.03	1991160.00	2.88	1276450.00	1.56
	dum6	1820902.00	2.99	-5791936.00	-1.15	-731580.50	-0.12
	dum7	2119644.00	6.6	-1344318.00	-0.59	835279.30	0.29
	dum8	-150699.50	-0.26	-7077909.00	-1.54	-2567787.00	-0.45
	dum9	-2563303.00	-3.74	-11000000.00	-1.96	-5436278.00	-0.78
	dum10	2610641.00	11.76	1298239.00	1.46	1975798.00	1.68
	dum11	164352.00	0.36	-4992350.00	-1.45	-1690801.00	-0.39
	_cons	-3496925.00	-6.87	-8935441.00	-2.43	-4515350.00	-1.22
alfalfa	npsoy_t1	6126.05	3.19	6160.02	2.57	8554.40	1.73
	npalfa_t1	-3992.33	-1.84	-5163.89	-1.94	-12290.28	-3.07
	npoh_t1	11337.61	4.56	11314.33	4.4	9053.23	3.06
	npoc_t1	-830.39	-1.64	322.17	0.28	-1882.51	-1.73
	land	0.07	3.73	0.41	2.03	0.59	2.64
	t	-18896.32	-10.81	-28444.98	-4.42	-32499.20	-4.76
	dum1	-2548963.00	-9.18	-7623049.00	-2.55	-10500000.00	-3.1
	dum2	-1953991.00	-20.12	-3301505.00	-4.13	-4139684.00	-4.42
	dum3	-1875860.00	-6.29	-7288508.00	-2.28	-10500000.00	-2.87
	dum4	-2093383.00	-8.4	-6551145.00	-2.49	-9253179.00	-3.05
	dum5	-964927.00	-16.31	-465713.20	-1.5	-206207.40	-0.61
	dum6	-1321534.00	-6.26	-5141013.00	-2.28	-7303263.00	-2.87
	dum7	-1896562.00	-16.71	-3617566.00	-3.55	-4671047.00	-3.94
	dum8	-1473697.00	-7.47	-4951623.00	-2.41	-7118897.00	-2.99
	dum9	-1327665.00	-5.61	-5570713.00	-2.22	-8176117.00	-2.83
	dum10	-1552458.00	-18.04	-2177988.00	-5.62	-2617039.00	-5.46
	dum11	-216850.00	-1.38	-2798655.00	-1.83	-4507484.00	-2.5
	_cons	1633404.00	9.71	-1122138.00	-0.69	-1862963.00	-1.18

other hay	npsoy_t1	3709.28	0.09	705.01	0.02	-38147.61	-0.65
	npalfa_t1	11337.61	4.56	11314.33	4.4	9053.23	3.06
	npoh_t1	-9570.94	-2.63	-9608.04	-2.56	-10514.01	-2.81
	npoc_t1	-741.18	-1.52	-667.80	-1.09	-564.02	-0.98
	land	0.04	2.6	0.05	0.47	0.17	1.04
	t	-2459.04	-1.46	-2843.41	-0.78	-6279.08	-1.26
	dum1	-829873.10	-3.23	-992711.60	-0.58	-2660657.00	-1.1
	dum2	-379202.60	-4.22	-420715.80	-0.93	-856941.50	-1.3
	dum3	-872290.70	-3.15	-1044783.00	-0.57	-2838633.00	-1.09
	dum4	810638.60	3.51	668880.20	0.44	-823245.50	-0.38
	dum5	-68765.71	-1.22	-51633.06	-0.29	121568.60	0.5
	dum6	-245583.20	-1.25	-368208.60	-0.29	-1620211.00	-0.89
	dum7	2664828.00	25.21	2610895.00	4.47	2041397.00	2.43
	dum8	895674.70	4.89	785392.50	0.67	-393669.60	-0.23
	dum9	332098.00	1.51	197212.40	0.14	-1229990.00	-0.6
	dum10	-63151.02	-0.79	-80741.66	-0.37	-269111.90	-0.82
	dum11	759159.10	5.15	679245.90	0.77	-196171.00	-0.15
	_cons	83606.47	0.49	-4051.46	0	-678409.10	-0.63
other crops	npsoy_t1	4271.08	3.01	6282.04	2.6	3123.65	1.24
	npalfa_t1	-830.39	-1.64	322.17	0.28	-1882.51	-1.73
	npoh_t1	-741.18	-1.52	-667.80	-1.09	-564.02	-0.98
	npoc_t1	-1544.59	-0.95	-5048.07	-1.68	-95.36	-0.05
	land	0.25	3.94	-0.94	-1.7	-0.27	-0.96
	t	-88676.68	-15.3	-56549.25	-3.29	-78668.97	-9.29
	dum1	-3332820.00	-3.45	14400000.00	1.74	4700580.00	1.07
	dum2	-1226796.00	-3.72	3521872.00	1.58	1083471.00	0.85
	dum3	-4604535.00	-4.44	14300000.00	1.62	4070437.00	0.86
	dum4	8747706.00	10.09	24300000.00	3.35	15900000.00	4.05
	dum5	859640.20	4.3	-858336.80	-1.02	156061.70	0.36
	dum6	-52819.08	-0.07	13300000.00	2.14	5969292.00	1.81
	dum7	-183149.90	-0.47	5863089.00	2.07	2702554.00	1.7
	dum8	-448690.10	-0.65	11700000.00	2.07	5162587.00	1.68
	dum9	10200000.00	12.43	25000000.00	3.63	17000000.00	4.57
	dum10	-181067.90	-0.71	2090993.00	1.88	1097051.00	1.49
	dum11	1587199.00	2.91	10600000.00	2.52	5899368.00	2.49
	_cons	169092.20	0.29	9761373.00	2.17	3962871.00	1.9

Table B2. Estimates for acreage share equations- prices normalized by corn price							
Parameter		SUR		3SLS-LAGGED PRICES		3SLS-CURRENT PRICES	
		Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
soybeans	npsoy_t1	0.005030	1	0.004448	0.84	-0.010617	-1.24
	npalfa_t1	0.000329	2.84	0.000336	2.37	0.000587	2.6
	npoh_t1	0.000329	2.84	0.000336	2.37	0.000587	2.6
	npoc_t1	0.000425	5.69	0.000460	4.73	0.000414	4.34
	land	0.0000000014	0.5	0.000000013	0.73	-0.000000008	-0.35
	t	0.004197	15.93	0.003875	6.77	0.004558	6.1
	dum1	0.275155	6.58	0.096716	0.36	0.419762	1.16
	dum2	0.290200	20.04	0.242042	3.35	0.326045	3.27
	dum3	0.266855	5.93	0.076450	0.26	0.423977	1.08
	dum4	0.002001	0.05	-0.154875	-0.65	0.129792	0.4
	dum5	0.123159	14.01	0.140336	4.98	0.106602	2.93
	dum6	0.186355	5.86	0.052187	0.26	0.296288	1.09
	dum7	0.226613	13.51	0.165442	1.79	0.274163	2.16
	dum8	0.089069	2.99	-0.033006	-0.18	0.190733	0.75
	dum9	-0.017449	-0.49	-0.166234	-0.73	0.109353	0.35
	dum10	0.297117	25.3	0.273726	7.85	0.311266	6.14
	dum11	0.097938	4.11	0.006999	0.05	0.175259	0.92
	_cons	-0.017464	-0.65	-0.113274	-0.76	0.082553	0.51
alfalfa	npsoy_t1	0.000329	2.84	0.000336	2.37	0.000587	2.6
	npalfa_t1	-0.000126	-0.71	-0.000284	-1.09	-0.001056	-2.57
	npoh_t1	0.000747	4.59	0.000759	4.54	0.000644	3.26
	npoc_t1	-0.000155	-3.18	-0.000020	-0.18	-0.000220	-2.25
	land	0.0000000025	1.41	0.000000040	1.95	0.000000052	2.42
	t	-0.001517	-9.06	-0.002565	-3.96	-0.002844	-4.38
	dum1	-0.272139	-10.21	-0.820960	-2.74	-1.013451	-3.16
	dum2	-0.236854	-25.39	-0.381968	-4.79	-0.437941	-4.99
	dum3	-0.248207	-8.67	-0.833367	-2.61	-1.049437	-3.04
	dum4	-0.253104	-10.58	-0.734894	-2.79	-0.917697	-3.21
	dum5	-0.102092	-18.13	-0.047845	-1.54	-0.030836	-0.96
	dum6	-0.203902	-10.07	-0.617073	-2.73	-0.760113	-3.16
	dum7	-0.232478	-21.41	-0.417968	-4.11	-0.487913	-4.39
	dum8	-0.213351	-11.27	-0.589375	-2.86	-0.738076	-3.28
	dum9	-0.211734	-9.34	-0.670533	-2.67	-0.848110	-3.1
	dum10	-0.204217	-24.88	-0.270671	-7.12	-0.298550	-6.78
	dum11	-0.129923	-8.63	-0.408563	-2.68	-0.526903	-3.09
	_cons	0.254402	15.82	-0.045015	-0.28	-0.074815	-0.5

other hay	npsoy_t1	0.000733	0.32	0.000268	0.11	0.000587	-0.21
	npalfa_t1	0.000747	4.59	0.000759	4.54	-0.001056	3.26
	npoh_t1	-0.000627	-2.72	-0.000611	-2.6	0.000644	-2.81
	npoc_t1	-0.000054	-1.89	-0.000061	-1.7	-0.000220	-1.21
	land	-0.0000000022	-2.27	-0.000000005	-0.72	0.000000052	-0.14
	t	-0.000094	-0.97	-0.000023	-0.11	-0.002844	-0.53
	dum1	-0.011472	-0.77	0.027591	0.28	-1.013451	-0.16
	dum2	-0.024404	-4.68	-0.014087	-0.53	-0.437941	-0.67
	dum3	-0.010418	-0.65	0.031370	0.29	-1.049437	-0.14
	dum4	0.059081	4.41	0.093492	1.07	-0.917697	0.39
	dum5	-0.012696	-3.88	-0.016610	-1.58	-0.030836	-0.75
	dum6	0.004971	0.44	0.034454	0.46	-0.760113	-0.03
	dum7	0.210045	34.01	0.223327	6.58	-0.487913	4.23
	dum8	0.065601	6.16	0.092510	1.35	-0.738076	0.58
	dum9	0.036571	2.86	0.069498	0.83	-0.848110	0.22
	dum10	0.003253	0.68	0.008043	0.63	-0.298550	0.25
	dum11	0.060093	7.03	0.080190	1.57	-0.526903	0.74
	_cons	0.070365	7.09	0.092040	1.67	-0.074815	1.12
other crops	npsoy_t1	0.000425	5.69	0.000460	4.73	0.000414	4.34
	npalfa_t1	-0.000155	-3.18	-0.000020	-0.18	-0.000220	-2.25
	npoh_t1	-0.000054	-1.89	-0.000061	-1.7	-0.000040	-1.21
	npoc_t1	-0.000125	-1.59	-0.000298	-2.06	-0.000090	-0.99
	land	-0.0000000062	-2.06	-0.000000059	-2.25	-0.000000019	-1.49
	t	-0.005006	-18.04	-0.003563	-4.39	-0.004799	-12.4
	dum1	0.054942	1.19	0.828822	2.15	0.254796	1.29
	dum2	-0.015482	-0.98	0.190610	1.84	0.042164	0.74
	dum3	0.016102	0.33	0.841623	2.05	0.232334	1.09
	dum4	0.594255	14.38	1.274064	3.77	0.773189	4.37
	dum5	0.088935	9.32	0.013108	0.33	0.071607	3.64
	dum6	0.165190	4.72	0.747650	2.58	0.315254	2.13
	dum7	0.088016	4.78	0.350945	2.67	0.160134	2.25
	dum8	0.132067	4.04	0.662158	2.51	0.271470	1.96
	dum9	0.671749	17.15	1.318414	4.1	0.840699	5.02
	dum10	0.035500	2.87	0.131970	2.59	0.067811	2.08
	dum11	0.231587	8.91	0.625340	3.18	0.338927	3.19
	_cons	0.224945	8.08	0.646102	3.07	0.320863	3.41

Table B3. Estimates for revenue share equations- prices normalized by corn price							
Parameter		SUR		3SLS-LAGGED PRICES		3SLS-CURRENT PRICES	
		Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
soybeans	npsoy_t1	0.0482793	1.07	0.0482495	1.04	0.1332729	2.88
	npalfa_t1	0.0133933	1.32	0.0123631	1.09	0.0187378	1.56
	npoh_t1	0.0133933	1.32	0.0123631	1.09	0.0187378	1.56
	npoc_t1	0.0818937	3.61	0.0715748	3.01	0.0638606	2.26
	land	-0.0822537	-1.5	-0.345458	-1.67	-0.2304024	-1
	t	0.0032704	9.8	0.0036197	8.28	0.0037959	9.1
	dum1	0.3201266	5.43	0.5980983	2.74	0.4719847	1.9
	dum2	0.2754696	10.92	0.3854383	4.45	0.3339014	3.35
	dum3	0.3261912	5.26	0.6138891	2.71	0.4821816	1.83
	dum4	0.1057694	1.92	0.3610834	1.79	0.2440235	1.04
	dum5	0.0561578	3.96	0.0053596	0.13	0.0258346	0.56
	dum6	0.2226181	4.51	0.4546606	2.49	0.348489	1.69
	dum7	0.2800222	9.5	0.4122814	3.96	0.3515586	2.93
	dum8	0.15616	3.32	0.373805	2.17	0.2751499	1.39
	dum9	0.0788538	1.48	0.3260025	1.67	0.2122211	0.94
	dum10	0.2743898	15.91	0.3357202	6.83	0.3044271	5.16
	dum11	0.1954988	4.91	0.3724668	2.65	0.2867659	1.73
	_cons	1.174363	1.35	5.376384	1.64	3.513071	0.98
alfalfa	npsoy_t1	0.0133933	1.32	0.0123631	1.09	0.0187378	1.56
	npalfa_t1	0.1017507	5.38	0.0993804	3.54	0.1245307	4.5
	npoh_t1	-0.0428705	-3.35	-0.0517725	-3.64	-0.0302622	-2.08
	npoc_t1	0.0116852	0.84	0.0440936	2.14	-0.0330474	-1.58
	land	0.0913428	2.25	0.9248113	4.05	0.4046465	2.01
	t	-0.0033105	-14.11	-0.00449	-9.56	-0.0032293	-8.51
	dum1	-0.2713046	-6.21	-1.149827	-4.75	-0.6216957	-2.88
	dum2	-0.2056636	-10.99	-0.5516226	-5.74	-0.3533435	-4.09
	dum3	-0.2431739	-5.32	-1.153007	-4.59	-0.6197889	-2.72
	dum4	-0.2066442	-5.07	-1.014628	-4.54	-0.5408855	-2.67
	dum5	-0.0345063	-3.28	0.1279722	2.8	0.0224028	0.56
	dum6	-0.2035592	-5.57	-0.9375635	-4.64	-0.4911721	-2.74
	dum7	-0.2085372	-9.51	-0.6263841	-5.42	-0.3822771	-3.69
	dum8	-0.2028992	-5.83	-0.892638	-4.68	-0.481446	-2.78
	dum9	-0.227811	-5.79	-1.012182	-4.67	-0.541422	-2.76
	dum10	-0.1450428	-11.13	-0.3368888	-6.15	-0.2393853	-4.78
	dum11	-0.1186172	-4.08	-0.6790376	-4.36	-0.3570638	-2.49
	_cons	-1.332774	-2.06	-14.61254	-4.03	-6.263298	-1.98

other hay	npsoy_t1	-0.0198498	-1.3	-0.0178856	-1.14	-0.0389049	-2.47
	npalfa_t1	-0.0428705	-3.35	-0.0517725	-3.64	-0.0302622	-2.08
	npoh_t1	0.0884484	7.06	0.0973602	6.99	0.0956743	6.82
	npoc_t1	-0.013749	-1.93	-0.0167299	-2.17	-0.0330763	-3.4
	land	-0.0202691	-1.14	-0.0082732	-0.12	0.0600555	0.73
	t	-0.0005515	-5.07	-0.0005316	-3.75	-0.0004749	-3.35
	dum1	-0.0034024	-0.18	-0.017326	-0.25	-0.0963711	-1.08
	dum2	-0.0079107	-0.97	-0.0137756	-0.5	-0.049193	-1.37
	dum3	-0.003479	-0.17	-0.0185443	-0.25	-0.1051231	-1.11
	dum4	0.0419984	2.35	0.0284834	0.44	-0.0483326	-0.57
	dum5	-0.0121848	-2.59	-0.0105598	-0.79	0.001347	0.08
	dum6	0.0078794	0.49	-0.003179	-0.05	-0.0670266	-0.91
	dum7	0.1176127	12.16	0.1115978	3.33	0.070957	1.64
	dum8	0.0113814	0.74	-0.0005355	-0.01	-0.0626882	-0.88
	dum9	0.020949	1.21	0.0082679	0.13	-0.0608421	-0.75
	dum10	0.0171787	2.96	0.0143507	0.9	-0.0111936	-0.52
	dum11	0.0273236	2.12	0.0172572	0.38	-0.0371771	-0.63
	_cons	0.3367477	1.19	0.1532302	0.15	-0.9179323	-0.71
other crops	npsoy_t1	0.0818937	3.61	0.0715748	3.01	0.0638606	2.26
	npalfa_t1	0.0116852	0.84	0.0440936	2.14	-0.0330474	-1.58
	npoh_t1	-0.013749	-1.93	-0.0167299	-2.17	-0.0330763	-3.4
	npoc_t1	-0.0447945	-1.8	-0.0714622	-2.54	0.0384056	1.16
	land	-0.0757789	-1.31	-0.5088887	-2.26	-0.0011331	0
	t	-0.0042384	-12.31	-0.0035341	-7.3	-0.0050506	-12.41
	dum1	-0.0331044	-0.53	0.4189442	1.76	-0.0829099	-0.33
	dum2	-0.0738787	-2.77	0.1009455	1.07	-0.0791871	-0.77
	dum3	-0.0729925	-1.12	0.3933377	1.6	-0.1055975	-0.39
	dum4	0.3974465	6.81	0.8117924	3.71	0.3676162	1.54
	dum5	0.1001064	6.71	0.0148949	0.33	0.1208665	2.63
	dum6	0.1036434	1.99	0.4821437	2.43	0.0549843	0.26
	dum7	0.0617841	1.98	0.2731574	2.41	0.0482965	0.39
	dum8	0.025749	0.52	0.3832537	2.05	-0.010523	-0.05
	dum9	0.6376983	11.35	1.043644	4.91	0.5936391	2.58
	dum10	-0.0419371	-2.28	0.0493964	0.93	-0.0258084	-0.42
	dum11	0.1196293	2.86	0.4070634	2.67	0.1080305	0.64
	_cons	1.466401	1.59	8.355831	2.33	0.205846	0.06

APPENDIX C

Table C1. Elasticities of acreage responses (3SLS-lagged prices)

	Corn price ($/bu)	Soybeans price ($/bu)	Alfalfa price ($/ton)	Other hay ($/ton)	Other crops ($/acre)
Corn acres	0.1407	-0.0309	-0.1174	0.0339	-11.6112
Soybean acres	-0.0154	-0.0758	-0.1241	-0.0281	4.7799
Alfalfa acres	-0.0174	-0.0369	-0.1843	0.1755	2.8124
Other hay acres	0.0073	-0.0122	0.2568	-0.1606	-0.2710
Other crops acres	-0.1836	0.1517	0.3001	-0.0198	10.3850

Table C2. Elasticities from acreage share responses (3SLS-lagged prices)

	Corn price ($/bu)	Soybeans price ($/bu)	Alfalfa price ($/ton)	Other hay ($/ton)	Other crops ($/acre)
Corn acreage share	0.1509	-0.0508	-0.0913	0.0136	-11.7867
Soybean acreage share	-0.0255	-0.0951	-0.0427	-0.0622	6.3561
Alfalfa acreage share	-0.0116	-0.0108	-0.1813	0.1711	1.2908
Other hay acreage share	0.0028	-0.0256	0.2781	-0.1558	0.5775
Other crops acreage share	-0.2061	0.2215	0.1776	0.0489	9.8624

Table C3. Elasticities from revenue share responses (3SLS-lagged prices)

	Corn price ($/bu)	Soybeans price ($/bu)	Alfalfa price ($/ton)	Other hay ($/ton)	Other crops ($/acre)
Corn revenue share	-0.2750	0.1886	-0.0235	0.0218	0.0881
Soybean revenue share	0.3094	-0.6478	0.1103	-0.0365	0.2646
Alfalfa revenue share	-0.1842	0.5268	-0.5925	-0.3600	0.6098
Other hay revenue share	0.4122	-0.4201	-0.8671	0.7831	0.0919
Other crops revenue share	0.2615	0.4788	0.2312	0.0145	-0.9859

APPENDIX D

Elasticities of acreage, acreage share and revenue share responses calculated using coefficients estimated with crop prices normalized by corn price

Table D1. Elasticities of acreage responses (3SLS-lagged prices)					
	Corn price ($/bu)	Soybeans price ($/bu)	Alfalfa price ($/ton)	Other hay price ($/ton)	Other crops price ($/acre)
Corn acres	0.0180	-0.0379	-0.0809	-0.0077	-0.0154
Soybean acres	-0.0183	0.0354	0.0475	0.0327	0.1308
Alfalfa acres	-0.0113	0.0137	-0.1616	0.2436	0.0272
Other hay acres	**-0.0016**	**0.0016**	**0.3540**	**-0.2068**	**-0.0565**
Other crops acres	-0.0002	0.0042	0.0030	-0.0043	-0.1274

Table D2. Elasticities from acreage share responses (3SLS-lagged prices)					
	Corn price ($/bu)	Soybeans price ($/bu)	Alfalfa price ($/ton)	Other hay ($/ton)	Other crops ($/acre)
Corn acreage share	0.0197	-0.0403	-0.0803	-0.0248	-0.0221
Soybean acreage share	-0.0196	0.0390	0.0413	0.0284	0.1526
Alfalfa acreage share	-0.0096	0.0102	-0.1206	0.2220	-0.0232
Other hay acreage share	-0.0048	0.0090	0.3584	-0.1983	-0.0776
Other crops acreage share	-0.0004	0.0054	-0.0033	-0.0069	-0.1317

Table D3. Elasticities from revenue share responses (3SLS-lagged prices)					
	Corn price ($/bu)	Soybeans price ($/bu)	Alfalfa price ($/ton)	Other hay price ($/ton)	Other crops price ($/acre)
Corn revenue share	**0.0807**	-0.0209	-0.1613	0.0016	0.0999
Soybean revenue share	-0.0343	**-0.5451**	0.1032	0.0681	0.4081
Alfalfa revenue share	-1.2635	0.4925	**0.7156**	-0.8376	0.8929
Other hay revenue share	0.0298	-0.4311	-2.0175	**2.9317**	-0.5130
Other crops revenue share	0.2966	0.7386	0.3385	-0.0807	**-1.2930**

APPENDIX E

Derivation of revenue share elasticities

$$share_i = p_i q_i / revenue$$

$$\eta_{ii} = \frac{\partial q_i}{\partial p_i}\frac{p_i}{q_i} = \frac{dln\ q_i}{dln\ p_i} \text{ own price elasticity}$$

$$\eta_{ij} = \frac{\partial q_i}{\partial p_j}\frac{p_j}{q_i} = \frac{dln\ q_i}{dln\ p_j} \text{ cross price elasticity}$$

$$\ln share_i = \ln p_i + \ln q_i - \ln revenue_i$$
$$\ln q_i = \ln share_i - \ln p_i + \ln revenue_i$$

$$\frac{\partial \ln q_i}{\partial \ln p_j} = \frac{\partial \ln share_i}{\partial \ln p_j} - \frac{\partial \ln p_i}{\partial \ln p_j} + \frac{\partial \ln revenue}{\partial \ln p_j}$$

$$\eta_{ii} = \frac{\beta_{ii}}{average\ share_i} + share_i - 1 \quad \text{own price elasticity}$$
$$\eta_{ij} = \frac{\beta_{ij}}{average\ share_i} + share_j \quad cross\ price\ elasticity$$

Derivation of acreage share elasticity

$$Ash_i = acreage\ share_i = \frac{acres\ of\ crop\ i}{total\ crop\ acres} = \frac{A_i}{A} = \beta_{ij} * p_j \text{ (from eq. 8)}$$

$$A_i = \beta_{ij} * p_j * A$$

$$\frac{\partial A_i}{\partial p_j} = \beta_{ij} * A_i$$

$$\ln Ash_i = \ln A_i - \ln A$$

$$\eta_{ij} = \frac{\partial \ln Ash_i}{\partial \ln p_j} = \frac{\partial \ln A_i}{\partial \ln p_j} = \frac{\partial A_i}{\partial p_j}\frac{p_j}{A_i} = (\beta_{ij} * A_i)\ \frac{p_j}{A_i} = \frac{\beta_{ij} * p_j}{average\ acreage\ share_i}$$