The Effect of Ethanol-Driven Corn Demand on Crop Choice

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Since the late 1990s, U.S. production of corn ethanol has risen rapidly. In response to high demand, driven in part by rising ethanol production, corn prices and corn production surged in 2007 when corn plantings reached their highest level since 1944. To increase corn acreage, farmers shifted land to corn from other crops or, possibly, returned uncultivated land (e.g., cropland pasture, CRP land) to corn production.

Even before 2007, however, "islands" of relatively high corn prices formed around ethanol plants in the Midwest. Price impacts were usually concentrated around an ethanol plant and ranged between 4.6 cents and 19.6 cents per bushel, with an average price increase of 12.5 cents at the plant site. Prices were also affected up to an estimated 68 miles from the plant (McNew and Griffith, 2005). Did these price island effects induce producers to shift their crop mix to include more corn? If localized changes did occur in the years before 2007, they may persist into the future even though corn prices have declined absolutely and in relation to prices for soybeans and other crop commodities.

Questions relating to crop mix are important because continuous corn, corn-intensive crop rotations, and shifting land from less intensive uses, like hay, into corn, can adversely affect the environment (Malcolm and Aillery, 2009). Continuous corn, for example, can mean higher levels of fertilizer and pesticide application as producers lose the natural soil fertility and pest control benefits of crop rotation. Land shifted from uncultivated crops to corn may also be more erosion-prone than other cropland. Lubowski et al. (2006), found that marginal cropland tends to be more erodible and more susceptible to nutrient runoff than other cropland. To the extent that these changes result in higher levels of soil erosion, nutrient runoff and leaching, or pesticide runoff and leaching, ground and surface water quality can be damaged.

This paper develops a discrete choice model that incorporates local prices, proximity to ethanol production facilities, and crop mix to understand the effect of ethanol-driven demand on corn acreage and crop mix. The primary data set is the 2005 Agricultural Resource Management Study (ARMS) survey of corn producers, collected by the Economic Research Service and the National Agricultural Statistics Service (NASS). A nested multinomial logit model (NML) is used to estimate model parameters.

Crop Choice Model

We consider four alternatives: corn, soybeans, wheat, and “other” crops that include hay, oats, barley, and a number of other, less frequently grown crops. Because crop choice is discrete, we use a probabilistic approach in modeling it. Return to land use can be specified using deterministic and random components:

$$R_{ij}(q_{ij}) = E\left(R_{ij}(q_{ij})\right) + \varepsilon_{ij} = \sum_k \beta_{ik} q_{ijk} + \varepsilon_{ij}$$

where R_{ij} is return to crop *i* on farm *j*, q_{ij} is a vector of explanatory variables with elements q_{ijk}, and ε_{ij} is an error term that captures idiosyncratic differences across farms.

If the error terms are independently distributed and follow a type I extreme value distribution, model parameters ($\beta_{ik}'s$) can be estimated using a multinomial logit. This property (also referred to as the independence of irrelevant alternatives or IIA) implies that the probability of choosing option A from a three choice set (A, B, C) will not affect the ratio of the probabilities of choosing B or C. If the probabilities of choosing A or B tend to vary together across individuals, however, error terms are correlated and IIA is violated. In the crop choice problem, correlation between the probability of choosing corn and soybean is likely because these crops tend to grow in rotation on high quality land.

To account for this correlation, we assume that the error terms follow a generalized extreme value (GEV) distribution. The GEV distribution assumes that alternatives can be separated into groups with correlation across alternatives within groups but without correlation across groups. The general GEV distribution can be written as $F(\varepsilon_1, \varepsilon_2, \varepsilon_3, ..., \varepsilon_n) = \exp[-G]$ where

$$G = \sum_{m=1}^{M} a_m \left(\sum_{I=1}^{I_m} e^{R_{mi}/(1-\sigma_m)} \right)^{(1-\sigma_m)} ,$$

m indexes the groups and σ_m is approximately equal to the correlation among alternatives within group m (see Maddala, page 71). We specify three groups: (1) corn-soybeans, (2) wheat, and (3) other crops. Assuming $a_m = a$, we can write:

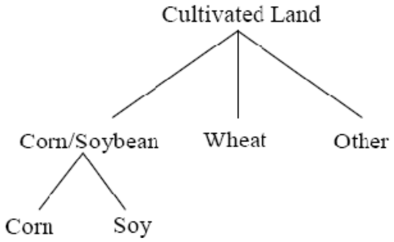
$$G = a\left(\left(e^{R_{cn}/(1-\sigma_{cnsb})} + e^{R_{sb}/(1-\sigma_{cnsb})}\right)^{(1-\sigma_{cnsb})} + e^{R_{wh}} + e^{R_{oh}}\right)$$

where $m = cnsb$ for the corn-soybean group, $m = wh$ for wheat, and $m = oh$ for other crops. The probability functions can be written as:

$$P_{mi} = \frac{ae^{R_i}}{G} \frac{\partial G}{\partial e^{R_i}} .$$

Manipulating the probability functions, as shown in Maddala, yields a nested logit model (see figure 1) with the choice between corn and soybeans (conditional on the choice of corn or soybeans) at the lower level and the choice among corn or soybeans, wheat, and other crops at the upper level.

Figure 1: Model of Crop Choice



Applying the probability formula directly, the unconditional probability of choosing corn (and, of course, the corn-soybean group) is:

$$P_{cnsb,cn} = \frac{ae^{R_{cn}/(1-\sigma_{cnsb})}}{G}\left(e^{R_{cn}/(1-\sigma_{cnsb})} + e^{R_{sb}/(1-\sigma_{cnsb})}\right)^{-\sigma_{cnsb}}.$$

The unconditional probability of soybeans is similar. The probability of choosing the corn-soybean group is equal to the sum of the unconditional probabilities of choosing corn or soybeans:

$$P_{cnsb} = P_{cnsb,cn} + P_{cnsb,sb} = \frac{a\left(e^{R_{cn}/(1-\sigma_{cnsb})} + e^{R_{sb}/(1-\sigma_{cnsb})}\right)^{(1-\sigma_{cnsb})}}{G}.$$

The probability of a specific land use, conditional on the choice of its group can be written as $P_{i|m} = P_{mi} / P_m$. The probability of choosing corn, conditional on the choice of the corn-soybean group, is:

$$P_{cn|cnsb} = P_{cn} \big/ P_{cnsb} = \frac{e^{R_{cn}/(1-\sigma_{cnsb})}}{e^{R_{cn}/(1-\sigma_{cnsb})} + e^{R_{sb}/(1-\sigma_{cnsb})}}.$$

The conditional probability of choosing soybeans is similar.

Using these probabilities, we can specify a binomial logit model of the choice between corn and soybeans, conditional on the fact that either corn or soybeans will be selected. Parameters are estimated only up to the factor $1/(1-\sigma_{cnsb})$. In estimating the lower level, we have normalized on the choice of soybeans, thus the probabilities of the lower level become:

(1) $$P_{cn|cnsb} = \frac{e^{R_{cn}/(1-\sigma_{cnsb})}}{1+e^{R_{cn}/(1-\sigma_{cnsb})}}$$

and

(2) $$P_{sb|cnsb} = \frac{1}{1+e^{R_{cn}/(1-\sigma_{cnsb})}}.$$

The probability of choosing wheat is $P_{wh} = \frac{ae^{R_{wh}}}{G}$, while the probability of "other" crops is similarly specified. Given model results at the lower level, the probability of choosing corn or soybeans can be re-written as:

$$P_{cnsb} = \frac{ae^{I_{cnsb}(1-\sigma_{cnsb})}}{G} = \frac{a\left(e^{R_{cn}/(1-\sigma_{cnsb})}+e^{R_{sb}/(1-\sigma_{cnsb})}\right)^{(1-\sigma_{cnsb})}}{G}$$

where the inclusive value representing the corn-soybean group in the crop model is:

(3) $$I_{cnsb} = ln\left(e^{R_{cn}/(1-\sigma_{cnsb})} + e^{R_{sb}/(1-\sigma_{cnsb})}\right)$$

and G can be written as:

$$G = a\left(e^{(1-\sigma\_cnsb)I_{cnsb}} + e^{R_{wh}} + e^{R_{oh}}\right).$$

Then the upper level probabilities can be written as:

$$P_{wh} = \frac{e^{R_{wh}}}{e^{(1-\sigma_{cnsb})I_{cnsb}}+e^{R_{wh}}+e^{R_{oh}}}$$

$$P_{oh} = \frac{e^{R_{oh}}}{e^{(1-\sigma_{cnsb})I_{cnsb}}+e^{R_{wh}}+e^{R_{oh}}}$$

$$P_{cnsb} = \frac{e^{(1-\sigma_{cnsb})I_{cnsb}}}{e^{(1-\sigma_{cnsb})I_{cnsb}}+e^{R_{wh}}+e^{R_{oh}}}$$

and can be estimated using MNL. Because the corn-soybean group has a lower level, we need to normalize on something other than the corn-soybean group; thus we choose to normalize on the “other” group. Given this normalization, probabilities can be rewritten as:

$$(4) \qquad P_{cnsb} = \frac{e^{R_{cnsb,upper}+(1-\sigma_{cnsb})I_{cnsb}}}{e^{R_{cnsb,upper}+(1-\sigma_{cnsb})I_{cnsb}}+e^{R_{wh}}+1}$$

$$(5) \qquad P_{wh} = \frac{e^{R_{wh}}}{e^{R_{cnsb,upper}+(1-\sigma_{cnsb})I_{cnsb}}+e^{R_{wh}}+1}$$

$$(6) \qquad P_{oh} = \frac{1}{e^{R_{cnsb,upper}+(1-\sigma_{cnsb})I_{cnsb}}+e^{R_{wh}}+1}.$$

Data and Estimation

The two-level nested logit model is estimated using a limited information maximum likelihood approach. The estimation proceeds by first estimating the lower level of the tree, i.e. the probability of a farmer harvesting a corn or soybean crop. The inclusive values are calculated as in equation (3) and are included as an explanatory variable in estimation of the upper level. The ARMS farm level data is used to construct the choices in both levels of the model: a proportion of corn or soybeans harvested (from total corn and soybean harvest) in the lower level, and a proportion of corn or soybeans, wheat, or “other” crop harvested (out of the summation of these crops harvested) in the upper level. The “other” crop category consists of cotton, sorghum for grain or silage, barley, oats, alfalfa and other hay, and sugar beets.

Because the ARMS surveys are complex, care must be taken when calculating the variance, standard errors, and significance of the parameter estimates for both levels. In the ARMS data, “each observation represents itself and many other farms through a weight or expansion factor. The concept is that the weighted estimate should be equivalent to a nonweighted estimate, with each observation repeated the number of times indicated by its weight." (Dubman, 2000). Given that we are trying to describe characteristics of a population using individual farm data, weighting is necessary; ARMS weights are based on value of sales and are provided in the ARMS dataset.

To estimate the variance of parameter estimates, the delete-a-group jackknife is used (Kott, 2001). The full ARMS sample is divided into fifteen nearly equal and mutually exclusive different sets. Using these different data sets, fifteen estimates or "replicates" of the statistic are created. One of the fifteen parts is eliminated in turn for each replicate estimate with replacement. Following this estimation, the full sample and replicate estimates are placed into a basic jackknife variance formula:

$$Variance\ (\beta) = {}^{14}/_{15} \sum_{k=1}^{15} \left(\beta_{(k)} - \beta\right)^2 \tag{7}$$

where β is the full sample estimate and $\beta_{(k)}$ is a replicate estimate with part k removed. (Dubman, 2000) This variance formula is used in our estimation to calculate the standard errors and t-statistics of β.

The data used in estimation of this model is constructed from various sources. The ARMS observations are drawn from the traditional Corn Belt, along with some other states including North Carolina and North Dakota. Operator characteristics and the relative importance of livestock to a particular farm are taken from ARMS. The livestock variable represents how much of the gross farm income is related to livestock sales and inventory. We also include a binary variable that indicates whether a single field on the farm that is planted in corn in 2005, has been classified as highly erodible land (1=highly erodible, 0=otherwise). This variable then acts as a proxy for the full farm. Other variables in our model include local prices of corn and soybeans, a local ethanol capacity index, and a soil productivity index. The price variable is a ratio of corn price to soy price, where both prices are an average of the last three months of 2004.

Using data on several thousand grain buying points, we used GIS to localize the corn and soybean prices to our individual observations. The price data was collected by the Farm Service Agency for the purpose of developing Posted County Prices used to implement a marketing loan program (Loan Deficiency Payments and Marketing Loan Gains). Median prices, by month, are developed for each buying location. To estimate the price available to a given farm, a distance weighted average of nearby purchase points is developed using GIS techniques. We assume that producer price expectations will be formed in the months immediately prior to planting; we use an average of October, November and December cash prices.

An index of ethanol production capacity is developed to capture the intensity of ethanol production—and related demand for corn—in a given area for a specific point in time. The base data including the location and production capacity of ethanol plants was developed by ERS and relies on data obtained from the Renewable Fuels Association. The index is built with a kernel density surfaces estimate with a 4 square kilometers spatial resolution and a bandwidth of 125 km (70 miles). McNew and Griffith (2005), suggest that ethanol plants influence local corn markets out to this distance.

To capture variation in land quality, we use National Commodity Crop Productivity Index (NCCPI) developed by soil scientists with the Natural Resources Conservation Service (Dobbs et al., 2008). NCCPI captures soil, landscape, and climate factors affecting the growth of commodity crops, in an index that lies within the unit interval. The index was initially developed for implementation of the Conservation Reserve Program.

In the lower level of the model, we include the price ratio, ethanol capacity index, an interaction term between price and ethanol capacity, soil productivity index, livestock value variable, highly erodible land indicator, and operator characteristics. We include the ethanol capacity index to capture any local effects of nearby ethanol plants that may not be captured by the corn/soybean price ratio. Because our price variables are based on traditional grain buying points, they may not capture price premiums that are offered directly to producers through contracts or other mechanisms. An interaction term between these two variables is included to determine whether the presence of ethanol capacity alters price response.[1] In the lower level of estimation, we expect the price ratio and ethanol capacity parameters to be positive.

The livestock variable captures on-farm demand for feed crops; livestock producers may be more inclined to grow corn because it is needed for feed. Operator characteristics include age, age squared, education (less than high school diploma, high school diploma and some college, bachelors degree and more), and occupation (1=farmer/rancher, 0=other).

At the upper level of the model, we include the ethanol capacity index, soil productivity index, livestock value variable, highly erodible land indicator, inclusive values from the lower level estimation, and operator education, occupation, age, and age

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[1] Because our preliminary work uses cross-sectional data, however, association between corn acreage and ethanol capacity could also indicate that ethanol plants have been cited in areas that are more likely to grow corn. Bringing in the 2001 ARMS survey data in subsequent versions of the analysis will allow us to examine this relationship more carefully.

squared. The inclusive value is calculated using equation (3), and is included in the corn-soybean equation in estimation.

We expect the ethanol capacity index parameter to be positive for the corn-soybean group, indicating that farmers are more likely to plant either corn or soybeans (which can be an indication of a corn-soybean rotation pattern), than “other” crops. As soil productivity increases, we expect that a farmer will be more inclined to plant a corn-soybean mix as these crops are typically grown on high quality land. The relative effect of ethanol capacity and land quality on the probability of producing wheat and other crops, however, is less clear. We have no specific expectation about the sign or magnitude of these parameters. Finally, a negative parameter is possible for the livestock indicator on both the corn-soybean group and wheat; this is because hay, which falls into the “other” group, is often used for livestock feed.

Because parameters in this model are not directly interpretable, we calculate and interpret the marginal effects and elasticities of the ratio of probabilities of choices, with respect to a variable of interest. Marginal effects and elasticities are reported for significant variables in both the lower and upper levels of the model in table 4 and table 5. The marginal effects are computed as the derivative of the ratio of two probabilities with respect to a particular variable of interest:

$$(8) \qquad \frac{\partial(P_j/P_m)}{\partial x_{ij}} = \frac{P_j}{P_m}(\beta_{ij} - \beta_{im})$$

where

$$P_j = \frac{e^{R_j}}{\sum_k^J e^{R_k}}.$$

In the case of the lower level, *j* is the probability of corn and *m* is the probability of soybeans, while in the upper level *j* is the probability of either the corn-soybean or wheat group being chosen, and *m* is the probability of the wheat or “other” group being chosen. In calculating the lower level marginal effects, the impact of the interaction term needs to be taken into account. If, for example, the variable of interest is the corn-soybean price ratio, then the marginal effect of the ratio of probabilities in choosing corn to soybeans due to a change in the price ratio is

$$(9)\qquad \frac{\partial(P_c/P_s)}{\partial price_c} = \frac{P_c}{P_s}\left[\left\{\beta_{price_c} + \left(\beta_{interact_c} * ethcap_c\right)\right\} - \left\{\beta_{price_s} + \left(\beta_{interact_s} * ethcap_s\right)\right\}\right].$$

The marginal effect with respect to ethanol capacity follows similarly.

Following the calculation of marginal effects, elasticities are also computed for relevant variables in both the upper and lower levels of the model. Again, care needs to be taken when examining the lower level with respect to price or ethanol capacity. If no interaction term is included in calculating the elasticity (for either level) then

$$(10)\qquad \varepsilon_{jx_{jk}} = \frac{\partial(P_j/P_m)}{\partial x_{jk}} * \frac{x_{jk}}{(P_j/P_m)} = x_{jk} * (\beta_{x_{jk}} - \beta_{x_{mk}}).$$

If either the price ratio or ethanol capacity is used to calculate the elasticity in the lower level, then

$$(11)\qquad \varepsilon_{jx_{jk}} = x_{jk} * \left\{\left(\beta_{x_{jk}} + \beta_{x_{jt}} * x_{jl}\right) - \left(\beta_{x_{mk}} + \beta_{x_{mt}} * x_{ml}\right)\right\}.$$

Estimation Results

Parameter results for the lower level are found in table 2. Only the corn/soybean price ratio, soil productivity index, and livestock indicator are significant in the lower level. Because of the inclusion of an interaction term between price and ethanol capacity, marginal effects and elasticities are also examined. The positive parameter on the price ratio suggests that as the price of corn increases relative to the price of soybeans, farmers are more inclined to harvest corn relative to soybeans. The marginal effect and elasticity value for this variable also indicate that the price ratio has a large impact on whether a farmer will choose to plant corn or soybeans. For example, with an elasticity greater than one, we know that a 10% increase in the price ratio (e.g. an increase in the price of corn, a decrease in the price of soybeans, or both) will increase the ratio of corn to soybeans plantings by almost 14%. Thus when farmers are choosing whether to plant corn or soybeans, local price effects have an impact on their decision.

The negative parameter value on the soil productivity index suggests that as soil productivity increases a farmer would be less likely to plant corn relative to soybeans. However, the marginal effect and elasticity of the soil productivity variable indicate that the move from corn to soybean (as soil productivity increases) would be relatively small; a 10% increase in soil productivity would decrease the corn/soybean probability ratio by only 4%.

Livestock is also significant in the lower level of estimation and is consistent with our expectations in that as the value of livestock on a farm increases, farmers are more likely to plant corn relative to soy. However the marginal effect of livestock appears to be small. With a 10% increase in the livestock indicator, the corn/soybean probability ratio will increase by about 3.5%. Thus, even with a large increase in livestock value, farmers only increase corn production by a small amount.

The parameter results for the upper level of crop choice are most often as expected, and can be found in table 2. Livestock, soil productivity, ethanol capacity, age, and age squared are all significant for both the corn-soybean and wheat group. The highly erodible land indicator is significant only for the wheat/other choice.

The livestock parameter estimates are negative for both the corn-soybean group and wheat, thus livestock farmers are less likely to harvest either corn or soy, or wheat, relative to the “other” crop. The marginal effects and elasticities for both of the crop choices demonstrate that a small increase in livestock value would not cause a significant decrease in corn-soybean or wheat production, relative to “other” crop production, most likely hay. On farms with large livestock enterprises, it might be more cost-effective for a farmer to grow hay rather than corn or wheat. It is also interesting to note that the elasticity of the change in probabilities of the corn-soybean group to wheat is positive, suggesting that as the value of livestock on a farm grows, the ratio of probabilities would increase, meaning that there is an increase in either corn or soybean production, or a decrease in wheat production.

The corn-soybean group has a positive parameter estimate for soil productivity, while wheat has a negative parameter estimate. Farmers will be more likely to plant either corn or soybeans relative to “other” if the soil productivity increases, although the change is relatively small. The opposite is true for the wheat choice; as soil productivity increases a farmer is less likely to plant wheat relative to “other” crops. Again the change in land use is small. However, when examining the ratio of probabilities of corn-soybean to wheat, the effect of an increase in soil productivity is quite large. If soil productivity increases by 10%, there is almost a 12% increase in the ratio of probabilities of corn-soybean to wheat, i.e. either the production of corn or soybeans will increase, or the production of wheat will decrease. This makes sense because corn and soybeans are more effective in taking advantage of high soil productivity.

The ethanol capacity index parameter values are positive on the corn-soybean group and negative for wheat. The effect on movement to a corn-soybean group relative to “other” is small; a 10% increase in local ethanol capacity will encourage a farmer to increase his corn-soybean production by only 2-3%. Farmers are less likely to move wheat into production relative to “other” if ethanol capacity increases. With a 6.5% decrease in wheat production for a 10% increase in ethanol capacity, this effect is larger than the move that a farmer would make for corn-soybean production. The elasticity of the probabilities of corn-soybean to wheat show the largest change in crop movement due to an increase in local ethanol capacity. If ethanol capacity increases by 10%, the probability ratio increases by over 9%; thus, farmers are likely to plant either more corn or soybeans, or less wheat. This is obvious in that a farmer would directly benefit from planting corn (quite possibly grown in rotation with soybeans), whereas planting additional wheat will not provide any benefit to the farmer with regards to an ethanol plant or local ethanol capacity.

The parameter estimates were positive on age and negative on age squared for both the corn-soybean and wheat choice. The marginal effects and elasticity values of these parameters indicate that as a farmer’s age increases, the probability of corn-soybean to other, or wheat to other increases by 3% and 6%, respectively. However, the elasticities for age squared suggest that this effect will taper off as age continues to increase. The highly erodible land indicator parameter was also significant for the wheat choice, and carried a negative value. The marginal effect for the ratio of the probability of wheat to “other” was also negative, implying that the probability of a farmer planting wheat relative to some other crop is higher when the farm is not classified as highly erodible. Some of the crops in the “other” group, particularly hay, are less likely to disturb the topsoil when harvested and minimize erosion, as compared to wheat.

Finally, the parameter estimate on the inclusive value is small and not significantly different from zero. Maddala mentions that this value should lie between zero and one, where a value of one indicates that the model can be reduced to a simple multinomial logit model. A value of zero suggests the opposite of a multinomial logit mode; rather the levels are separate and present independent and separate choice situations. This could indicate that corn and soybeans are almost always grown on high quality land, while other crops are relegated to land of lower quality. Nonetheless, it seems unlikely that the margin between corn-soybeans and other crops is fixed. Further investigation is needed.

Conclusion

Ethanol-driven demand on corn acreage and crop mix can have environmental and other implications, thus it is important to understand the impact that local prices have on the land use decisions of individual farmers. It is also essential to examine land use in relation to other common farm crops that may compete with a corn-soybean rotation, to fully understand the impacts of local prices and local ethanol capacity.

This paper has used individual farm level data to attempt to draw out the effects of prices, ethanol capacity, soil quality, and even livestock, on farmers’ decisions to plant corn or soybean, wheat, or some other crop. By nesting the choice of corn or soybeans, we are able to relax the restriction of independence of irrelevant alternatives, and model the choice between corn and soybeans without focusing on the correlation of their errors, and use this estimation to look at land use change on a larger scale.

In both levels of estimation, soil productivity and livestock value influence a farmer's decision to plant corn or soybeans, wheat or some other crop. The estimation of our lower level confirms that local prices have a strong influence on whether a farmer will choose to plant corn or soybeans, while our upper level estimation may suggest that an increase in local ethanol capacity will encourage farmers to plant corn or soybean relative to both wheat and "other". However, caution is required in the interpretation of the ethanol capacity parameter estimates. Given that our data includes only a cross-section of farms, these parameter estimates could also reflect the likelihood that ethanol plants are sited in areas where corn is likely to be grown. Future work will utilize additional data and will focus on the acreage response to a change in ethanol capacity over time.

Using FIML estimation on our model may improve our results; at the very least, we might achieve more efficient parameter estimates for both levels of estimation. The inclusive value parameter is of concern; future work will involve a re-examination of the model specification.

If local prices and ethanol capacity increases, and farmers move more land to a corn-soybean rotation, it might be possible to extend this work to related environmental impacts. Land use change could be linked to nutrient runoff and loads in water, possible soil erosion, and other environmental impacts from continuous corn rotations. Through examining the change of land use and crop mix due to increases in ethanol demand, we can better understand the impacts prices have on the decision making for farmers.

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Table 1

Descriptive Statistics for Choice Options and Variables in Estimation

	Mean	Standard Deviation	Minimum	Maximum
Lower Level Choices				
Corn	0.5885	0.2165	0.0610	1.0000
Soybean	0.4115	0.2165	0.0000	0.9390
Upper Level Choices				
Corn-Soybean	0.8068	0.2317	0.0196	1.0000
Wheat	0.0796	0.1488	0.0000	0.8363
Other	0.1136	0.1761	0.0000	0.9804
Explanatory Variables				
Price of Corn	158.7737	315.7788	-6611.7400	221.2002
Price of Soy	463.6876	508.7076	-6512.0500	554.8909
Price Ratio	0.3477	0.0492	-0.0699	1.0771
Livestock Indicator	0.2315	0.3148	-0.3443	1.5697
Ethanol Capacity Index	0.0032	0.0047	0.0000	0.0239
Age	53.5969	11.4902	-	-

	Frequency	Percent
Occupation		
1 = Farmer/Rancher	929.00	89.59
0 = Otherwise	108.00	10.41
Highly Erodible Land		
1 = HEL	192.00	18.51
0 = Otherwise	845.00	81.49
Education		
eda-Less than HS Diploma	80.00	7.71
edb-HS and some college	691.00	66.63
edc-B.S. and more	266.00	25.65

Table 2

Probability of Choosing Corn or Soybean Crop Given Corn-Soybean Group

Conditional Probability Coefficient Estimates - Normalized on the Choice of Soybean

Corn|(Corn-Soybean)
n=1037

	Corn	
Corn-Soybean Price Ratio	3.9775	**
	(2.1245)	
Soil Productivity Index	-0.9045	***
	(-4.2879)	
Highly Erodible Land	0.0797	
	(0.7821)	
Educ: HS Diploma/Some College	-0.0884	
	(-0.7577)	
Educ: Bachelor's Degree and More	-0.1281	
	(-0.7972)	
Occupation as Farmer/Rancher	-0.0787	
	(-0.7311)	
Age	-0.0056	
	(-0.1586)	
Age^2	0.0001	
	(0.2316)	
Livestock Importance	1.50931	***
	(9.2297)	
Ethanol Capacity Index	-121.9000	
	(-0.6757)	
Interaction(Ethanol Cap, Price)	396.9640	
	(0.7475)	
Constant	-0.6433	
	(-0.4702)	

T-statistics in parentheses
* significant at 10%; **significant at 5%; ***significant at 1%

Table 3

Probability of Choosing Corn-Soybean, Wheat or “Other” Crop

Coefficient Estimates of Crop Choice - Normalized on the Choice of Other

	Corn-Soybean		Wheat	
Educ: HS Diploma/Some College	0.1723		0.1392	
	(0.4635)		(0.3004)	
Educ: Bachelor's Degree/More	-0.2837		0.7433	
	(-0.9973)		(1.1337)	
Occupation as Farmer/Rancher	-0.1916		0.0724	
	(-0.8184)		(0.2059)	
Age	0.0650	*	0.1050	**
	(1.5090)		(1.7804)	
Age^2	-0.0007	**	-0.0011	**
	(-1.8271)		(-2.0883)	
Livestock Importance	-1.944	***	-2.6242	***
	(-4.3399)		(-7.4554)	
Soil Productivity Index	1.3713	**	-1.2256	**
	(1.9374)		(-2.0722)	
Highly Erodible Land	-0.2777		-0.3814	*
	(-0.8184)		(-1.5841)	
Ethanol Capacity Index	83.4848	**	-205.165	***
	(2.5529)		(-4.0545)	
Inclusive Value	-0.4481		-	
	(-1.1251)		-	
Constant	0.7064		-1.8003	
	(0.5194)		(-1.1689)	

T-statistics in parentheses
* significant at 10%; **significant at 5%; ***significant at 1%

Table 4

Lower Level Marginal Effects and Elasticities

Lower Level Estimation
Choice = Corn or Soybeans Given (Corn-Soybean) Group
Normalized on Soybeans

Probability of Corn to Probability of Soybeans

	Marginal Effects	Elasticities
Price Ratio	7.9882	1.3816
Livestock	3.0338	0.3494
Soil	-1.8181	-0.4113

Table 5

Upper Level Marginal Effects and Elasticities

Upper Level Estimation
Crop Choice = Corn-Soybeans, Wheat, or Other
Normalized on Other

Probability of Corn-Soybean to Probability of Other

	Marginal Effects	Elasticities
Ethanol Capacity	949.276	0.2703
Livestock	-22.1089	-0.4501
Soil	15.5928	0.6236
Age	0.7390	3.4834
Age Squared	-0.0011	-2.0297
Highly Erodible Land	-0.1869E-14	-

Probability of Wheat to Probability of Other

	Marginal Effects	Elasticities
Ethanol Capacity	-136.45	-0.6641
Livestock	-1.7453	-0.6074
Soil	-0.8151	-0.5574
Age	0.0698	5.6266
Age Squared	-0.0007	-3.3763
Highly Erodible Land	-0.6419E-16	-

Probability of Corn-Soybean to Probability of Wheat

	Marginal Effects	Elasticities
Ethanol Capacity	57927.7	0.9344
Livestock	136.423	0.1574
Soil	521.155	1.1810
Age	-8.0248	-2.1432
Age Squared	0.0899	1.3465
Highly Erodible Land	0.5573E-14	-