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# SPATIAL COMPETITION AND ETHANOL PLANT LOCATION DECISIONS

By

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Abstract

This article estimates factors that impact location decisions by new ethanol plants using logistic regression analysis and spatial correlation techniques. The results indicate that location decisions are impacted by the agricultural characteristics of a county, competition, and state-level subsidies. Spatial competition is particularly important. Existence of a competing ethanol plant reduces the likelihood of making a positive location decision and this impact decreases with distance. State-level subsidies are significant and a very important factor impacting ethanol location decisions.

***Key Words**: ethanol, location decisions, spatial correlatio*

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## I. Introduction

An important change in U.S. grain consumption is corn use for ethanol. The ethanol industry has been expanding during the past decade and the rapid increase in ethanol production has been driven to a large extent by government policy. The ethanol industry receives government support through federal and state subsidies, a renewable fuels standard.[1] As the ethanol industry continues to grown, there are a number of aspects of this growth to consider. One is the location of new ethanol plants. This article estimates factors that impact location decisions by ethanol plants using logistic regression analysis and spatial correlation techniques.

Estimation results indicate that location decisions are impacted by the agricultural characteristics of a county, competition, and state-level subsidies. Spatial competition is particularly important. All else equal, existence of a competing ethanol plant reduces the likelihood of making a positive location decision and this impact decreases with distance. State-level subsidies are significant and a very important factor impacting ethanol location decisions.

## II. Model Specification of Ethanol Plant Location Decisions

U.S. production of corn-based ethanol, which represents all of the ethanol currently produced commercially in the country, rose from 1.63 billion gallons in 2000 to 4.86 billion gallons in 2006, a 300% increase (Renewable Fuels Association 2007).[2] Furthermore, new production facilities are continually being built or planned. There are a total of 115 ethanol plants operating nationwide as of April 2007 with a capacity to produce 5.75 billion gallons

[2] Long term growth of the ethanol industry will require yield and productivity increases (Meyer, 2006; Smith, 2006; Sosland Publishing, 2006) and additional acres shifted to corn, which could come from changes in rotations (Hart 2006, Fatka 2006),

annually, and there are an additional 86 plants that are under construction or are expanding that will increase annual capacity by 6.34 billion gallons to about 12 billion gallons (Renewable Fuels Association 2007). ProExporter (2006) indicated there were an additional 369 projects on the drawing boards representing an additional 24.7 billion gallons of ethanol capacity (as reported in Mann Global Research). According to projections from the Energy Information Administration (EIA) (2006a), ethanol production will increase to nearly 10 billion gallons in 2015.

We specify a discrete choice model for ethanol plant location. The choice variable is county location and the explanatory variables are factors that explain comparative advantages (agricultural characteristics for each county, policy variables, and firm competition) for the plant to locate in a given county. Specifically, denoting systematic factors as $X_j$, the probability that an ethanol plant locates in county $j$ is:

$$Prob\ (Y_j = 1) = F(I_j)$$

where

$$I_j = \alpha + CX_j$$

and, if $F(\cdot)$ is a logistic distribution, then

$$\text{(1)} \qquad \text{Prob } (\text{Y}_\text{j} = 1) = \frac{\exp(I_j)}{1 + \exp(I_j)}.$$

The indicator function, $I_j$, in equation (1), however, ignores that the payoffs from a given location may be correlated to the location of other ethanol plants. As in Sarmiento and Wilson (2005, 2007), the logistic regression with spatial correlation in the choice set is:

$$\text{(2)} \qquad I_j = \alpha + CX_j + \beta_1 SL_j = \Gamma Z_j(\gamma)$$

and

$$SL_{-j} = \sum_{k \neq j} D_k exp(-Dist_{jk}/\gamma),$$

where $Dist_{jk}$ is the distance between plants $j$ and $k$; and $D_k = 1$ if an ethanol plant locates in county $k$, and $D_k = 0$ else. If $\beta_1 > 0$, and there are decreasing marginal transportation costs ($\gamma > 0$), then the probability of the ethanol plant locating in county $j$ increases with the proximity to other ethanol plants. The probability of building an ethanol plant in location (county) $j$ thus depends partly on location of other plants and the distance between competitors.

In addition to the spatial lagged dependent variable in (2), ethanol plant location decisions are impacted not only by corn production in the same county but also neighboring counties, and this effect depends on the distance across regions. To capture the spatial lagged explanatory variables (related to plated corn acreage, $C_k$), we add the index function:

$$SEL_j = \sum_{k \neq j} \exp(-Dist_{jk}/\gamma)C_k$$

where the dampening parameter $\gamma$ is assumed the same across spatial index functions. Equation (2) can thus be further characterized as

(3) $$I_j = \alpha + CX_j + \beta_1 SL_j + \beta_2 SEL_j$$

## III. Data

The data source on plant location decisions stem from the Renewable Fuels Association (2006) and the *Ethanol Producer Magazine* (2006). Agricultural data, including area planted and yields for corn, soybeans, and wheat, were obtained from the National Agricultural Statistics Service (NASS) (1995-2005) by county. Livestock inventories by state (county) were also taken from NASS. The amount of subsidy to ethanol production was derived for each state. Values for this variable were obtained from ProExporter (2006). States with specific ethanol subsidies are South Dakota and Kansas (3 cents/gallon), Nebraska (7 cents/gallon) and Minnesota, Missouri and Wisconsin (8 cents/gallon). The data were assembled on a county basis (3,400 observations).

## IV. Analysis of results

Estimation

Distance in the spatial indexes in (3) of the discrete choice model with spatial correlation enters non-linearly because of uneven frequencies when defining lags in a spatial framework. Available software designed to estimate dichotomous choice models with spatial correlation data is not readily available. Sarmiento and Wilson (2005) thus developed a procedure to estimate the discrete choice of plant location with an algorithm that converges easily. The algorithm is developed based on concentrating the logistic likelihood function in terms of the non-linear coefficient in the spatial correlation function (Sarmiento and Wilson 2005; Sarmiento and Wilson 2007). In particular, the estimator of (1) with the index function in (3) is obtained by solving the optimization:

$$(4) \qquad \underset{\gamma}{\mathrm{Max}} \ \ln L(\gamma)$$

$$\text{s.t.} \ \ \Sigma_i (y_i - \Lambda_i) \mathbf{Z}_i(\gamma) = 0$$

where

$$\ln L(\gamma) = \Sigma_i y_i \ln\{\Lambda_j\} + \Sigma_i (1 - y_i) \ln\{\Lambda_j\}$$

and

$$y_i = 0 \text{ or } y_i = 1.$$

Convergence of the algorithm estimated using GAUSS to solve the non-linear logit model in (4) is illustrated in Table 1. The algorithm converges at $\gamma = 9$.

The estimated scale parameter $\gamma$ shows the degree of firm interrelation increasingly intensifies as firms are more closely located to each other. The value of $\gamma$ indicates the rate at which interrelation across firms decreases with distance. A positive value for $\gamma$ is consistent with the premise that transportation costs increase at a decreasing rate. In ethanol, a positive $\gamma$ indicates that the effect of competition on location decisions is more intense when the plants are more closely located.

*Econometric results*

Estimation results are shown in Table 2. Several of the agricultural variables are highly significant. Corn yield has no significant effect on plant location, but yields of other crops have negative and statistically significant effects on ethanol plant location. Of interest are that total planted acres and acres planted to corn have positive and statistically significant effects on ethanol plant development. Simply, counties with more planted area in total (reflecting in part CRP effects), more area planted to corn, and lower yields of competing crops, have a greater likelihood of ethanol plants locating in that county. Crop production risk (Herfindahl) index has no explanatory effect on plant location (consistent with Sarmiento and Wilson 2005).

The impact of livestock is important. Both cattle and hogs in county *j* have a positive effect on plant location in that county. We experimented with different measures of feed concentrate demands, but these results were not significant. These results are largely a reflection of the prospective local demand for feeding of the ethanol byproduct, DDGs. DDGs have difficult shipping and logistical requirements and hence the ability to feed them near the point of ethanol production is important. These results explain why there are concentrations of ethanol production in regions that have large livestock inventories, including dominant feeding regions without corn production (e.g., Texas). The results also show that both cattle and hogs on feed are important, but the elasticity of the former is greater. This reflects that cattle have a greater ability to consume DDGs than other species.

The results show that the effect of state subsidies is positive, as expected, and its explanatory power is significant. The quantitative effect of the subsidy is illustrated in Figure 1. Simply, assuming all else constant, a greater subsidy increases the probability of a plant being located in a county in that state. Some states (e.g., Minnesota, Nebraska, amongst others) have made extensive use of subsidies to attract plants. However, subsidies alone will not attract investment, as having a large supply (production) of corn and livestock inventories to absorb the DDGs is also important.

The spatial impacts are important and, if not included in the econometric analysis, would result in a misunderstanding of the location decisions. There are two spatial impacts that are important in explaining ethanol location decisions. One is the spatial lag with respect to corn production. Amongst the explanatory variables, only acreage planted to corn has a statistically significant spatial lag effect. That is, statistically, only one spatial lagged explanatory variable is consistent with the data. Results indicate that the spatial externalities in county *j* (neighboring counties' corn production) have a positive effect on ethanol plant development in county *j*. These results are important. An ethanol location decision is impacted not only by corn production in its own county, but it is also impacted by corn production in neighboring counties. This likely is a result of the need to procure corn from more than the county in which the plant is located, but also from neighboring counties, all of which impact the expected payoff in comparing location decisions.

The other form of spatial interdependence is the distance to competing plants. This is referred to as spatial competition, and it has a negative impact on local plant development. These results show that the effect of competition on plant location is negative, and its effect sharply decreases with distance. Figure 2 shows the effects of competition on the probability that a plant locates in a given county. These results show that within about 30 miles the inter-plant spatial competition is important. It reduces the likelihood of locating within that range. At 60+ miles apart, the impact on the probability of location in county *j* is near nil. Thus, existence of competition decreases the probability of building a plant in that county, when controlling for other effects, and this impact decreases with distance. This value quantifies the impact of competitor plants in the county and the spatial autocorrelation of competitor plants. The result indicates that existence of competitor plants reduces the likelihood of *de-novo* ethanol plant locations. This is expected and no doubt is reflective of the desire of a new plant to want to avoid competition in procurement with incumbent plants.

*Interpretation of probabilities*

The model was used to illustrate the probability of ethanol location decisions. To do so, we used the values of the right-hand side variables for each observation. From these, we generated the predicted probability. These are shown in Figure 3 where the shading reflects the probabilities of a plant being located in that county. In addition, we overlaid existing plants on these probabilities.

The results show the effects of the critical variables and illustrate a fairly intense probability of location in the traditional high corn-producing regions (e.g., Iowa and Illinois). It also shows that in states with greater state subsidies, in addition to large corn production (e.g., Minnesota, Nebraska), the probabilities of location are larger. Finally, it shows that in some regions with extensive livestock feeding (e.g., Texas, California) there is a higher probability of a plant location even though these regions have neither extensive corn production nor state subsidies.

## V. Summary and Implications

Ethanol is one of the fastest growing industries in the U.S. agricultural sector. The growing demand for ethanol has resulted in mammoth investments in value-added agriculture and intense competition among states to attract ethanol plants. The purpose of this study is to analyze and determine factors that impact location decisions by new ethanol plants.

The model is a discrete logit model of location decisions by new ethanol plants and is specified and estimated using spatial autocorrelation techniques. This allows an explicit specification to capture spatial impacts on the dependent variable. In addition to the spatial autocorrelation and interdependencies, the model includes other agricultural variables and state-level subsidies.

The results indicate that location decisions are impacted by the agricultural characteristics of a county, competition, and the state-level subsidies. Notably, counties with large areas planted to corn, lower yields of competing crops, and larger cattle inventories are more likely to attract a new ethanol plant. These decisions are also impacted by spatial competition in two forms. One is the spatial lag of corn production in neighboring counties. This suggests that an ethanol plant location decision is impacted by corn production within the county as well as in neighboring counties. The second is spatial relations amongst competitors. Simply, existence of a competing ethanol plant reduces the likelihood of making a positive location decision, and this impact decreases with distance. Finally, state-level subsidies are significant and a very important variable impacting ethanol location decisions.

These results have important private and public sector implications. From a private location decision perspective, these results clearly indicate there are a multitude of factors impacting location decisions. Corn supplies are very important, as well as competing crops. In addition, cattle/hog inventories are important as a source of feed demand for the byproduct DDGs. As a result, one can expect ethanol plant locations to be concentrated primarily in counties with large corn production and/or in counties with large cattle/hog inventories. Indeed, this is what is being observed with heavy concentration in corn-producing states (Iowa, Illinois, Nebraska, and Minnesota) and in counties in Texas which are heavy feeders. Finally, competing ethanol plants are important and detract from further expansion. This impact is not only local within a county, but has a spatial dimension as well.

There are also public sector implications. At least six states have programs to entice ethanol plants. Our results suggest these programs are effective. Certainly, states such as Minnesota, South Dakota and Nebraska, each of which have ethanol subsidies, have a large number of ethanol plants. However, other factors such as corn production and cattle inventories are important and in some states are not dominated by the state subsidy.

Finally, the logit model with spatial correlation in the choice set used in this study is useful not only in the ethanol sector that was analyzed here, but could be applied in many other sectors in agricultural industries. For most of these industries, spatial impacts of competition and procurement are important, and ignoring them would result in biased estimates and a misunderstanding of factors that impact these decisions. As shown here, the spatial impacts are important to understanding these types of spatial location decisions.

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**Table 1: Convergence Conditional Likelihood Algorithm**

| $\gamma$ | Log Likelihood |
|---|---|
| 3 | -396.9 |
| 4 | -396.0 |
| 5 | -395.2 |
| 6 | -394.7 |
| 7 | -394.4 |
| 8 | -394.2 |
| 9 | -393.7 |
| 10 | -394.2 |
| 11 | -394.3 |
| 12 | -394.4 |
| 13 | -394.6 |
| 15 | -395.0 |
| 20 | -395.9 |
| 100 | -397.1 |

**Table 2: Ethanol Location Model with Spatial Effects**

| Variable | Coefficient | t-value | Derivative x Variable Mean Value |
|---|---|---|---|
| Constant Term | -4.8128 | -14.90 | N.A. |
| Corn yield | 0.0006 | 0.43 | 0.0100 |
| Yields of other crops | -0.0019 | -1.51 | -0.0487 |
| Planted Acreage Corn | 0.2599 | 2.79 | 0.0338 |
| Planted Acreage Total | 0.1037 | 2.30 | 0.0400 |
| Herfindahl | 0.2625 | 0.42 | 0.0025 |
| Total Livestock inventory | 0.0000 | -0.89 | -0.0109 |
| Ethanol subsidy $/gallon | 3.9787 | 3.33 | 0.0049 |
| Cattle on Feed | 0.0004 | 2.29 | 0.0112 |
| Hogs on Feed | 0.0001 | 2.65 | 0.0097 |
| Spatial Competition | -22.59 | -2.70 | -0.0123 |
| Corn Spatial Lag | 0.0001 | 2.51 | 0.0075 |
| | | | |
| Log Likelihood | | | -393.7 |

*Change in the probability from percentage change in the explanatory variable.

**Figure 1. Change in Probability of Plant Location Due to State Subsidy ($per gallon**

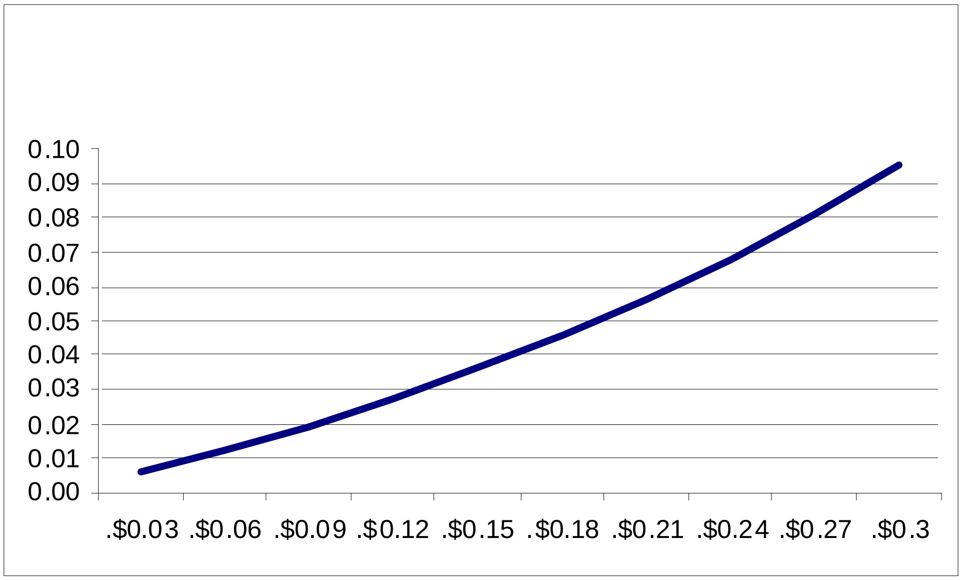


**Figure 2. Change in Probability of Plant Location due to Competition, by Distance.**

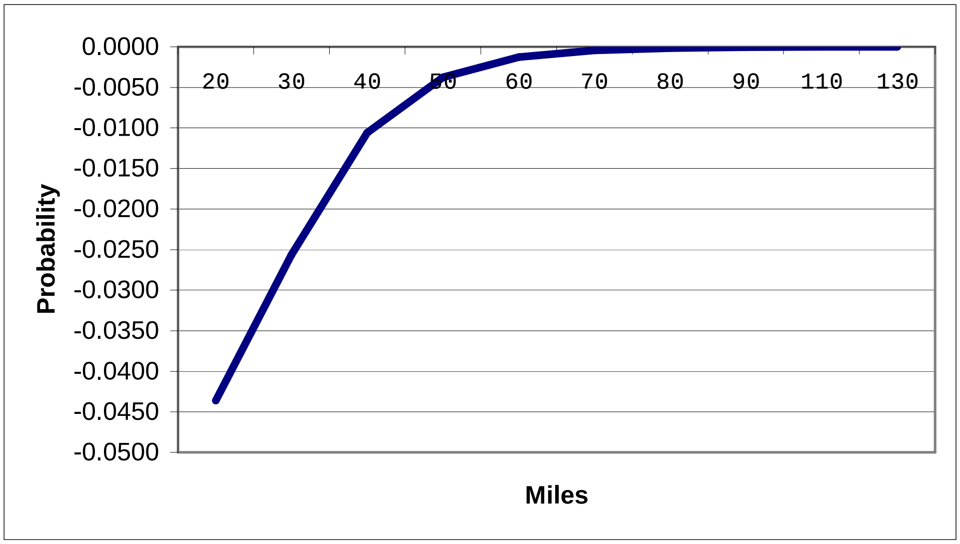
0.0000
-0.0050
-0.0100
-0.0150
-0.0200
-0.0250
-0.0300
-0.0350
-0.0400
-0.0450
-0.0500
Probability
20
30
40
50
60
70
80
90
110
130
Miles

**Figure 3. Probability of Plant Location with Existing Plant Locations**