

ABSTRACT

FATAL, YEHUSHUA SHAY. Ethanol Plant Siting and the Corn Market. (Under the direction of Walter N. Thurman).

Corn-based ethanol production has affected U.S. agriculture in general and the corn market in particular for the last several years. This study provides practical insights on the linkage formed between the two industries. The study aims to answer questions related to ethanol industry growth such as: where will the next ethanol plants be located, what will be their capacities, and what will be the plant siting effect on corn supply and price in the plants' regions? Some of these questions have never been addressed in the literature while some have only been casually researched.

The first chapter of the dissertation provides background on the ethanol industry. The second chapter investigates how changes in ethanol plant capacity affect corn supply geographically around the plant. The study is based on a county-level analysis of the 48 contiguous states for the years 2002-2008. The empirical analysis uses a non-linear least squares (NLS) model for estimating the key parameters and accounts for spatial autocorrelation. The results indicate that locating an ethanol plant in a county stimulates additional acres of planted corn within a 286-mile radius around the plant. An additional one million gallons of annual ethanol capacity is estimated to increase planted corn by 5.21 acres in the county in which the plant is located. This effect diminishes linearly to zero as the distance between the plant and other counties approaches 286 miles. In order to establish confidence intervals for the NLS estimators I utilize both residual and block bootstrap techniques. To account for spatial autocorrelation across counties, I employ a spatial error model.

The third chapter examines how changes in ethanol plant capacity affect corn basis in the plant's region. The study employs data on ethanol plant capacity as well as corn basis throughout the United States for the years 2002 through 2008. The empirical analysis uses a non-linear least squares (NLS) model for estimating the key parameters. The results indicate that there is a positive effect of ethanol plant siting on the corn basis surface around the plant. The estimated effect on basis equals 0.0193 cents per bushel for every additional annual million gallons at the plant location. The effect found diminishes linearly to zero as the distance between the market and the ethanol plant reaches 103 miles. Aggregating the effect of all plants within 103 miles from each corn market location yields an effect of up to 13 cents per bushel depending on the market location, number of plants and their capacities, and the year.

The fourth chapter investigates the various determinants of ethanol producer decisions for plant location and plant capacity using a county-level dataset for the years 2002 through 2008 in the 48 contiguous U.S. states. Different models are employed for the decisions. The location decision analysis is based on a Multinomial Logit model whereas the analysis of plant capacity is based on a Random Effects Tobit Model. I find that ethanol plant location and capacity decisions are mainly influenced by corn availability around the plant, competition from other plants, and the number of cattle located in the same county.

Ethanol Plant Siting and the Corn Market

by
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DEDICATION

To my lovely wife and precious kids.

BIOGRAPHY

Shay Fatal earned his Agriculture Economics B.S. at the Hebrew University of Jerusalem, Israel in 2005. In the pursuit of acquiring high level education, Shay initially achieved a Masters degree (2007) and later a Ph.D. in Economics (2011) at North Carolina State University. While earning his Ph.D. and writing this study, Shay worked at the North Carolina Solar Center as a research associate on projects conducted for the U.S. Department of Energy and the U.S. Department of Agriculture on subjects related to the economic implications of renewable energies.

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Chapter 1: Ethanol Industry Background

1.1 Ethanol Industry Growth and Drivers

Between the years 2002 and 2008 the number of corn-based ethanol plants in the United States grew from 49 to 129 (see Figure 5). Over the same period, annual ethanol production capacity increased from about two and a half billion gallons to almost eight billions gallons. These growth rates of 160% in the number of plants and 220% in ethanol production capacity relied on the availability of corn as a feedstock. As the ethanol industry expands, the link between the energy and agriculture sectors is tightening. Three major factors enabled the increase in ethanol production capacity: new energy regulation, a ban on MTBE (Methyl Tertiary Butyl Ether), and ethanol production incentives.

The main contributors to change in U.S. energy policy were the first and second Renewable Fuel Standards (RFS) acts. The RFS mandates require gradually increasing ethanol production in the United States over several years. The first RFS requirement was a part of the EPAct (Energy Policy Act) of 2005 while the second RFS was part of the EISA (Energy Independence and Security Act) of 2007. The stated goals of the EISA are to reduce U.S. energy dependence and greenhouse gas emissions. Whereas the first RFS served as the building block for an ethanol volume mandate, the second RFS was an expanded version of the first RFS. In order to fulfill the second RFS mandate and produce more ethanol, production capacity in the United States has started to grow. Figure 6 and Figure 7 show the requirements of both RFS mandates.

A different regulatory change was the MTBE ban imposed by several states. MTBE, used as a fuel additive to reduce carbon monoxide emissions, was found to contaminate

ground water and therefore was banned in many states. As a result, a substitute chemical was needed to oxygenate gasoline. Gasoline refiners began using ethanol instead of MTBE and consequently the demand for ethanol increased.

Federal and state level incentives in the form of a tax credit and an excise tax credit for ethanol producers and blenders have played a significant role in the accelerated growth of the ethanol industry. These incentives increase the attractiveness of ethanol production and induce prospective ethanol producers to engage in the industry. For more details see chapter 4 section 2.4.

1.2 Corn As a Feedstock

In addition to its use in ethanol production, corn is a basic commodity used by many industries. Corn is a basic ingredient in the food industry. It is also an input into feed for the meat industry such as cattle, hogs, and poultry. Furthermore, the United States is a net corn exporter. As a result growth in the ethanol industry, more corn has been diverted to ethanol production. This effect is causing non-ethanol corn consumers to compete with ethanol producers for corn availability. This implies a corn price increase in the short run mitigated to some extent by a supply response from corn producers. In fact, following the significant jump in U.S. ethanol production around 2002, production of corn increased to meet growing demand. As Figure 8 shows, not only did corn production increase, but the share of corn directed to the ethanol industry also rose significantly after 2002.

It is important to note that some of the corn production increase is caused by the increase in corn yields over time. Figure 27 shows historical U.S. planted corn and yield levels. In order to realize the true willingness of farmers to grow corn and exclude the yields factor, using planted corn measures instead of corn production will be more accurate. Table 1 provides a more detailed look at corn supply and demand. For example, corn production increased from about 9 billion bushels in marketing year 2002/03 to 13

billion in 2007/08. The share of ethanol production from total production of corn rose from about 11% in marketing year 2002/03 to 23% in 2007/08. Planted corn area grew from 79 million acres in 2002/03 to 93.5 million in 2007/08.

As an alternative to corn, cellulosic material can also be used to produce ethanol.

However, the process is more costly. Cellulose is the prime component of a plant cell wall and is very common. Until the technology of converting cellulose to ethanol turns to be more efficient economically, corn will remain the dominant feedstock for ethanol production in the United States.

1.3 Corn-Based Ethanol Production Process and Co-Products

Corn-based ethanol can be produced in one of two ways: wet mill or dry mill. The main difference between the wet and dry mill processes is the initial treatment of the corn. In a wet mill process the corn kernel is separated into starch, fiber, protein, and germ prior to fermentation whereas in a dry mill process the corn is ground entirely into flour. The wet mill process is mainly designed to produce food and feed products such as corn syrup, corn oil, and gluten meal, although ethanol can be produced instead of corn syrup using the starch of the corn.

In contrast, a dry mill produces ethanol as the main product but also results in Dried Distillers' Grains with Solubles (DDGs) and CO₂ as the co-products. The dry mill process became more common when ethanol industry growth started accelerating around the time when the first RFS mandate went into effect (2005). In the dry mill process, corn is ground to flour (meal) and then is mixed with water to form a mash. Later, enzymes are added to convert starch into simple sugar (dextrose). Next, yeast is added to the mash to ferment the sugar to alcohol. After fermentation, distillation of ethanol takes place. After that, excessive moisture is dehydrated from the ethanol to create 200 proof ethanol. The final step involves the addition of gasoline to the ethanol produced in order to denature it and prevent human consumption of the alcohol. The yield of ethanol and

its co-products in a dry mill production process are as follows: for every bushel of corn (56 pounds), about 2.7 gallons of ethanol, 17 pounds of DDGs and 18 pounds of CO₂ are produced. The DDGs are a desirable feed mainly for cattle, however it can be suitable for other livestock such as swine and poultry.

1.4 Ethanol Plant Siting Decision and Requirements

Choosing the criteria for a maximum profit ethanol plant is not an easy task. Ethanol producers have many variables to take into consideration when planning a new plant. For instance, producers have to think and decide about issues such as where to locate the plant such that corn and ethanol shipping costs are minimized, what will be the plant size, where the corn for the ethanol production will come from, what will be the corn price paid and how producers can minimize it, where are the major markets for their produced ethanol and the co-products, how can they utilize the maximum from the federal and state level incentives that are offered to ethanol producers, and what labor pool will they face in the plant location. These and many other questions need to be answered before the actual construction of the plant has begun.

This multiple dimensional problem is complex, and especially because all of the considerations have to be taken simultaneously. Because some of the considerations affect each other, finding the optimal solution is difficult. For example, the location decision determines the corn availability to the plant, therefore the plant capacity should be in line with this corn availability constraint, otherwise the cost of shipping corn from remote areas will increase production costs. A different example is the dilemma of either building the plant in an area with relatively cheap corn but where competitors are next door or locating the plant in an area where the new plant would gain some monopolistic power however at the cost of serving as a pioneer plant in a plant-free region.

In addition to these decisions, there are certain requirements for smooth plant operation, for example, an efficient transportation network, energy and water. Other requirements include emission control, air quality, construction and operation permits.

Chapter 2: The Effect of Ethanol Plant Siting On Planted Corn Acreage

2.1 Introduction

Only one study has examined the effect of placing an ethanol plant on corn prices; none have studied corn supply response to ethanol plant siting. This chapter contributes new insights on how a change in regional ethanol plant capacity affects corn supply in the plant's region.

Because corn is the most common feedstock for ethanol production in the United States today, gaining insights into the corn industry and its relationship to the ethanol industry will be valuable. The relationship between growing corn and ethanol plant siting is dual. The availability of corn attracts ethanol plants, while the existence of nearby ethanol plants increases local corn production. The first causality is explained in the next sentence, whereas the second is the core of this paper. Ethanol plants are attracted to corn growing areas because corn can account for 50-70 percent of ethanol input cost, depending on corn price¹. Understandably, ethanol plant producers prefer to locate their plants near the input feedstock, corn. As previous studies (Fatal, 2011b and the paper by Wilcox, English and Stewart, 2008) show, proximity to input markets is the most important determinant for locating an ethanol plant. In this way, ethanol plants are able to reduce input shipping costs. Moreover, the smaller the distance traveled from corn source to the plant, the smaller the uncertainty of having corn in time for production.

¹ See "Guide for Evaluating the Requirements of Ethanol Plants", The Clean Fuels Development Coalition, The Nebraska Ethanol Board and USDA, Summer 2006.

The attraction of ethanol plants to intensive corn production areas such as the Corn Belt² is supported by Figure 9.

It is clear from this figure that the majority of ethanol plant owners decided to locate their production plants in the Corn Belt, which is a saturated corn area (see Figure 10).

Another way to look at the attractiveness of excess corn supply regions, such as the Corn Belt, is that these areas are more likely to have lower corn prices, as indicated in Figure 11.

In order to understand the current and future effects of the ethanol industry on corn supply and demand, there is a need to account for the following statement: On the one hand, total corn supply in the United States shows signs of adjustment to the additional corn needs of the growing ethanol industry. But on the other hand corn consumption by the ethanol industry is increasing and expected to continue to rise as mandated by the Renewable Fuel Standard (RFS). Figure 5 along with its table demonstrate the change in U.S. ethanol capacity between the years 2002 and 2008. The second RFS sets a total U.S. ethanol production requirement of 36 billion gallons by the year 2022, where 15 billion gallons out of the total will be produced from corn by the year 2015 (see Figure 7).

In the case where corn supply fails to catch up with the increasing mandate, the likely result is higher corn prices. Higher corn prices raise farmers' revenue and therefore provide an incentive for farmers to allocate more land and other resources for growing corn at the expense of growing other crops such soybeans and wheat. Consequently, the quantities produced of soybeans and wheat decrease and their prices increase along with corn price. An alternative to allocating more land for corn production, besides shifting land from other crops, can be dedicating additional lands that are not currently used for

² The Corn Belt region mainly includes the states of Iowa, Indiana, Illinois, and Ohio. Also included are, parts of South Dakota, North Dakota, Nebraska, Kansas, Minnesota, Wisconsin, Michigan, Missouri, and Kentucky.

crop production. According to the USDA, cropland used as pasture, reduced fallow, and acreage returning to production from expiring Conservation Reserve Program contracts are all land uses that were converted to corn production due to increases in corn price. However, it is reasonable to assume that change in land designation usually takes more time to react to corn price increase than changes in the crop rotation behavior of farmers. Moreover, bringing additional land into corn production is likely to occur after a sustained period of high corn prices and not just a temporary price increase. Figure 28 shows historical U.S. corn price received by farms.

Farmers consider the incentive of higher corn prices as a motivation to increase their corn supply and hence their total revenue. One strategy of farmers to raise local demand for corn is to own ethanol plants. Because ethanol plants use corn for ethanol production, placing a plant in a specific region increases demand for the grain and therefore increases its price. Prior to the swift growth in the ethanol industry, corn farmers owned a large portion of the ethanol plants in the market. Today, a smaller share of the total ethanol plants is owned by farmers.

One major reason for the decrease in ethanol plant ownership by farmers is their lack of capital for keeping up with plant size increases (Alexander & Alcala, 2006). Before 2006, farmers operated and maintained small and medium-scale ethanol plants through community cooperatives. Nevertheless, as additional large-scale ethanol plants entered the market, the cost of building such large plants was beyond traditional debt and equity structures of farmers. Between the years 1999 and 2005, farmers owned around 70% of the total number of plants under construction. However, this changed later when the ethanol industry experienced a large-scale expansion in 2006. At the same time, private investors had higher capital availability than most farmers and their local communities, and thus built larger plant sizes (100 million gallons and above). Figure 12 demonstrates how farmers' share of new construction has changed over time including the sudden drop

in 2006 when private investors realized that the ethanol industry can offer a good return for their investment.

To understand a farmer's decision to increase corn production, a general description of what factors affect farmers' decisions is needed. Farmers face the decision of what combination of crops to grow in order to maximize their profits taking into account a land size constraint. Using this constraint along with agronomic considerations and farmers' expectations for several indicators will determine farmers' decision of what crop to grow and how many acres to allocate to each crop.

One of the major agronomic considerations for a farmer is crop rotation benefit. Without any special incentives to grow corn, farmers who grow soybeans and corn typically plant a year of corn followed by a year of soybeans (corn-soybeans rotation). Growing corn one year after growing soybeans the previous year provides many advantages to farmers. For example, corn yield is higher when farmers use a corn-soybean rotation. In addition, using a corn-soybean rotation requires less tillage and lower amounts of nitrogen fertilizer and pest control chemicals. But instead of a corn-soybean rotation, farmers may opt to use a corn-corn-soybean rotation, which means two years of planting corn followed by one year of planting soybeans. Farmers choose a corn-corn-soybean rotations only if the market offers a sufficient incentive, such as a higher corn price, to offset the additional cost and lower yield that result from the deviation from the corn-soybeans rotation. Other important factors affecting a farmer's decision include expected future crop price, input costs, crop water needs, and weather forecasts that might affect yields.

Understanding how ethanol plant siting affects the amount of planted corn around the ethanol plant is important for many parties. Knowing the local supply adjustment pattern of corn to the introduction of new ethanol plants nearby can provide beneficial information to an ethanol producer. Because availability of corn is crucial for production, having more information on future corn availability has a huge impact on sustainable profitability and the existence of the plant. Furthermore, increases in future

corn supply around the plant will support future plant expansion once market conditions encourage it.

Examining the causality of ethanol plant siting on planted corn can also help U.S. policy makers understand the implications of the biofuel policy regime, such as the Renewable Fuel Standard, on corn supply response. Understanding the dual relationship between ethanol and agriculture industries that help both feed each other's growth is vital for the success of the two. Additionally, policy makers can use the results of this paper to evaluate the effect of ethanol industry growth on farmers and vice versa.

The following examples demonstrate how U.S. policy makers can benefit from the results of this paper. First, as the ethanol industry expands, there is a need to ensure enough corn will be available to support industry growth. Unless a different feedstock can be found to replace corn (cellulosic ethanol for instance), a lack of corn may restrict further industry growth. In a more extreme case, where a corn price increase can offset plant profits, the result may cause plants to go out of business. In order to promote viable growth in the ethanol industry, policy makers need to have more information about future corn availability besides how much corn is available today. Information on corn supply response to the introduction of new ethanol plants is essential.

Second, having more information on how ethanol industry expansion affects farmers and alters their reactions can assist policy makers in adjusting government agriculture programs so that they can better achieve their goals. A good example is the role of agricultural subsidy programs. Increasing corn production as a result of a higher corn price implies increases in the total revenue of farmers. Significant changes in farmers' revenue can cause old government support programs to be redundant or unsuitable. One example is the corn marketing loan rates subsidy. The subsidy provides farmers short-term funds to meet expenses until the corn is marketed. For the last several years corn prices have exceeded marketing loan rates and no payments have been made. A different example relates to rural development. Policy makers who are interested in providing

more business and income to farmers in rural areas and increasing local tax revenue can make better predictions of how locating a new ethanol plant in an area will affect corn growers. The ethanol plant will not only increase corn prices, but also decrease shipping costs as the plant serves as a closer terminal for their product (see McNew & Griffith 2005).

Other parties who may benefit from the paper's results include ethanol industry investors and lenders, farmers who produce corn or buy Dried Distillers' Grain (DDGs), and ethanol buyers.

2.2 The Theoretical Model

In order to answer the question of how ethanol plant siting affects surrounding corn acreage, a model based on two key variables is required. The first variable represents the change in the ethanol industry while the second represents the change in the corn market caused by the change in the ethanol industry. In other words, I must use both variables to model the change in corn as a function of ethanol capacity. The first key variable is an ethanol plant indicator, which measures the change in the surrounding ethanol plants relative to each region of analysis (a U.S. county). The second is a corn variable, which measures the change in corn supply within the county as resulting of the change in capacity of nearby ethanol plants. Because ethanol plants vary by their total production capacity, plants' corn needs are different. A good candidate for representing nearby ethanol plants is the Total Ethanol Production Capacity variable. This variable applies to all counties and is measured as the sum of capacity for all plants within a certain radius distance from a county's centroid (the determination of the radius used to calculate total ethanol capacity is explained later). The variable Total Ethanol Production Capacity changes over time as ethanol plants are added or subtracted in the area in and around the county. The variable also captures plant capacity expansions.

A county has a few candidate variables to represent corn in the model, such as total production and planted acreage. For the purpose of this paper, the variable planted corn was preferred to Corn Production for several reasons. First, planted corn is less noisy than corn production. Corn production might be affected by severe weather such as low/high temperature or precipitation levels, while planted corn is not. Also, this paper investigates corn supply reaction to ethanol plant siting, therefore planted corn is a better candidate as it proxies for farmers' intentions and partials out corn yields' increase over time. Figure 13 Figure 14 show the distribution of counties with respect to planted corn quantities for years 2002 and 2008. Note, the analysis of this paper considers only those counties that have planted corn in at least one of the years of interest, between 2002 and 2008.

Given measures for the ethanol industry and corn supply, I start with the following simple model:

Equation 1 The Effect of Ethanol Capacity on Planted Corn

$$A_{it} = \alpha + \beta \sum_{j=1}^N C_{jt} + \varepsilon_{it}$$

where:

A_{it} = planted corn for county i in year t , measured in acres,

C_{jt} = ethanol production capacity of nearby plant j in year t , measured in annual million gallons per year (N plants),

ε_{it} = error term of the model for county i in year t .

The summation of all C_j 's gives us the total ethanol production capacity of all plants nearby to county i . Therefore the interpretation of the coefficient β is the effect of a unit increase in nearby ethanol capacity on corn acreage. Figure 15 demonstrates which

ethanol plants will be considered as nearby plants. That is to say, these are the ethanol plants within a specific radius distance from the county centroid.

Equation 1 is a simple and straightforward model, and does not reflect other important considerations. In particular, it does not capture that the effective ethanol capacity decreases smoothly with distance from the county centroid, and not discontinuously. As you get further away from the ethanol plant, you would expect the effect of ethanol plants on planted corn in the county to weaken. For instance, an ethanol plant with 100 million gallons 10 miles away from the corn source should have a greater impact on corn growers than the same plant 200 miles away.

The model can account for this effect by adding another term based on the distance between ethanol plant j to county centroid i (D_{ij}). Total ethanol production capacity weighted by the distance between the county and the ethanol plant will be called Effective Capacity (EC) in this paper. The capacity weight will equal one when D_{ij} is equal to zero and will diminish to zero as D_{ij} increases, until the point where $EC = 0$ (also known as Zero Effective Distance, or ZED). Equation 2 suggests an expanded model that incorporates the effect of distance between ethanol plants and the county on Effective Capacity.

Equation 2 The Effect of Ethanol Capacity on Planted Corn Using Effective Capacity (EC)

$$A_{it} = \alpha + \beta \sum_{j=1}^N \text{Max}(1 - \gamma D_{ij}, 0) C_{jt} + \varepsilon_{it}$$

Where D_{ij} is the distance between county i and plant j measured in miles.

The value of γ is the discount factor by which actual capacity (C_{jt}) is weighted by distance D_{ij} . The value of γ will be determined directly from the radius distance³ that will be chosen to calculate the total ethanol production capacity around the county. Figure 16 shows how ethanol plant capacity is discounted by distance.

In order to calculate the total ethanol production capacity surrounding the county, there is a need to determine the radius distance. The larger the radius, the higher total ethanol production capacity will be since the result from the calculation will contain more plants. The decision about what radius to use for the analysis is not an easy task. From preliminary research of the ethanol industry, it turns out that ethanol plants mostly get their corn supply from within 50 miles of the plant. In the study "Ethanol and the Local Community" conducted in 2002, AUS Consultants and SJH & Company used a 50-mile radius for estimating growing corn demand by ethanol plants as a contribution to farmer revenue. Their reasoning for using 50-mile radius is based on dry mill ethanol supply characteristics. These characteristics indicate that the vast majority of corn comes to the plants from within a 50-mile radius in order to minimize grain transportation costs. For more details, see USDA Ethanol Transportation Backgrounder (September 2007).

The decision about the right radius can be a matter of discretion and subject to critique. Would it not be more appropriate to let the data tell us what should be the right radius?

A useful approach is to perform a non-linear least squares using different radii. By running the model many times with different radii, I can compare the fitness of the model to the data for each radius. The radius specification that provides us with the best fitness will be the chosen radius. In order to decide what makes a better fitness, I need to define the criterion used to base our decision. The criterion for choosing the correct

³ From equation 2:

$EC=0$ where $1-\gamma D = 0$, which implies that $\gamma = 1/D$, or one over radius distance.

radius will be the value of sum of square errors (SSE) that result from the model. Like in most econometric models, I strive to increase the model explanatory power and reduce the error term as much as possible. Therefore, I will choose the radius specification with the lowest SSE value. Once the radius is determined, the value of γ will be determined automatically ($\gamma = 1/\text{radius}$).

Because it is not possible to calculate confidence intervals or standard errors of either γ or the radius from the methodology described above, there is a need to develop a complementary methodology for providing this missing part. The suggested approach for finding the confidence intervals includes a resampling technique with replacement (bootstrapping) of the residuals from the estimated non-linear least squares model. Then, construct the dependent variable recursively using all other explanatory variables and estimates from the non-linear least squares results. The following provides more details on the bootstrapping technique.

Let $e_t = [e_{1t} \ e_{2t} \ \dots \ e_{nt}]'$

be the $(n \times 1)$ residual vector from the model, where $t=2,3 \dots T$, and

e_t^r be the resampled residual with replacement version of the vector e_t .

Now, I can reconstruct the dependent variable (Y) recursively using the following:

$$Y_2^r = X_2\beta_1 + Y_1\beta_2 + e_2^r$$

$$Y_3^r = X_3\beta_1 + Y_2^r\beta_2 + e_3^r$$

$$Y_4^r = X_4\beta_1 + Y_3^r\beta_2 + e_4^r$$

$$Y_5^r = X_5\beta_1 + Y_4^r\beta_2 + e_5^r$$

$$Y_6^r = X_6\beta_1 + Y_5^r\beta_2 + e_6^r$$

$$Y_7^r = X_7\beta_1 + Y_6^r\beta_2 + e_7^r$$

and

$$Y = [Y_2^r \ \dots \ Y_7^r]$$

where Y_1 is taken from the original dataset and Y_2^r, \dots, Y_6^r are generated recursively and X is the matrix of all explanatory variables (but lagged corn) and β_1 is the non-linear least squares estimator (excludes lagged corn) from the actual data. β_2 is the non-linear least squares estimator for lagged corn.

The model in equation 2 is more comprehensive and therefore more realistic but still incomplete. As mentioned in the introduction, farmers may change their crop rotation behavior, which will affect the quantity of their planted corn. In order to control for crop rotation, I can use lagged values of corn and soybeans in equation 2.

2.3 Econometric Model

The appropriate econometric model for dealing with many counties for several years is a panel data model. That is to say, a panel with seven time periods (2002-2008) and 2,193 cross sections (the number of U.S. counties that meet the criterion of producing corn at least one year during 2002-2008). The following First Difference (FD) model is derived from equation 2 and contains additional variables such as lagged corn and lagged soybeans acreage for incorporating farmers' crop rotation preferences. Note, the constant α is dropped and used instead are the same number of time dummy variables as the number of years.

Equation 3 The Estimated Model

$$\Delta A_{it} = \sum_{t=2002}^{2007} \varphi_t D_t + \beta \sum_{j=1}^N \text{Max}(1 - \gamma D_{ij}, 0) \Delta C_{jt} + \delta \Delta A_{it-1} + \theta \Delta S_{it-1} + \varepsilon_{it}$$

Where:

$i = 1, 2, \dots, 2193$ (counties),

$t = 2002, 2003 \dots, 2007$ (6 periods),

ΔA_{it} = differenced planted corn in period t , measured in acres,

D_t = time fixed effects, $t = 2002, 2003 \dots, 2007$,

ΔC_{jt} = differenced ethanol production capacity of plant j in period t , measured in annual million gallons,

D_{ij} = distance between county i and plant j , measured in miles,

ΔA_{it-1} = differenced lagged value of planted corn in period t , measured in acres,

ΔS_{it-1} = differenced lagged value of planted soybeans in period t , measured in acres,

ϵ_{it} = idiosyncratic error for county i in period t ,

$\text{Var}(\epsilon_{it}) = \sigma^2$ is the variance of the error term of the model.

The role of the time dummy variables in this model is to control for variables affecting planted corn that are excluded from the model and that change over time but not by county. Examples are the corn futures prices, diesel prices for shipping, and farmer input costs. Additionally, the summation of all C_j 's provides the total ethanol production capacity of all plants within radius from county i . The sign of the coefficient β is expected to be positive as additional ethanol capacity is expected to increase planted corn. On the contrary, the larger distance between county i and plant j the smaller the effect on planted corn in county i . Consequently, the sign of the coefficient γ , which is the distance discount factor, is expected to be positive (in the model there is a minus sign before γ).

As opposed to expectations about previous coefficients, the sign of the lagged soybean coefficient can be either positive or negative. The sign will depend on whether farmers are willing to sacrifice agronomical benefits using their standard rotation behavior in favor of higher corn prices. A positive coefficient ($\theta > 0$) would indicate that the usual farmer rotation of corn-soybeans behavior is maintained. For instance, if the difference in planted soybean in the first period, say 2003 was positive, then it is expected that the

difference in planted corn in the second period, 2004, will be positive too (corn-soybeans rotation). Alternately, if $\theta < 0$ then the farmer behavior deviates from the corn-soybean rotation. If planted soybean in the first period was positive, then the difference in planted corn in the second period will be negative (corn-corn-soybeans rotation). Farmers might observe higher corn prices and as a result decide to plant corn although they planted corn last year. This kind of farmers' action favors short-run gains by increasing current revenue (because of higher corn price) over long-run rotation benefits.

One last consideration I need to account for before running the model is spatial autocorrelation. Because counties are geographic neighbors, they are likely to have unobservable similarities and thus suffer from high correlation among them. That is to say, for every given period, any two neighbor counties are likely to have positive correlation in the error term $E(\epsilon_{it}\epsilon_{jt}) > 0$. One way to account for spatial autocorrelation is to calculate another set of confidence intervals for the estimators using a block bootstrapping technique (Hall 1985). This approach resamples observations with replacement from the original dataset in a block form. For each observation (county) withdrawal from the data, the all spatial block (a county and its neighbors) is pulled out. In this way, the bootstrapping will incorporate spatial autocorrelation into the estimators' standard errors.

2.4 Data

Data on ethanol plants for the years 2002 through 2008 are taken from the RFA (Renewable Fuel Association, <http://www.ethanolrfa.org/>). The dataset is built on seven annual reports (every February) for the years 2002 through 2008 and includes information on 143 plants (see appendix 1 for the full plant list) that produced ethanol during the years of analysis. The variables available are, the plant's name, feedstock used in production (the paper used only plants with corn as a feedstock), and nameplate

capacity (the maximum production level the plant is permitted to produce). Several ethanol firms had multiple plants in the dataset and only one aggregate name plate capacity for all of them. Therefore, capacities for individual plants had to be recovered by contacting the firms or by using their internet web sites. Location of U.S. ethanol plants is based on the information from the RFA and Ethanol Producer Magazine (<http://www.ethanolproducer.com/>). Latitude and Longitude coordinates of the plants had to be collected separately using the plants' addresses.

Because the most detailed corn production data available are on a county level, county data from all 48 continental U.S. states were collected from the USDA. The relevant counties for the analysis are only those that produced corn in at least one of the years during 2002 and 2008 (2,193 counties met this criterion). The dataset includes county-level planted corn and soybeans in acres for the years 2001 through 2008 (year 2001 was necessary for lagged values for the year 2002). The data also includes a FIPS ID code (Federal Information Processing Standards) unique for every county. All data are accessible through the National Agricultural Statistics Service web site (<http://www.nass.usda.gov/>). Coordinates for U.S. counties were taken from GIS software (Global Information System).

Data on ethanol plant capacities are reported once a year, usually in February. Corn is grown usually from May to September and harvested around September to October; therefore only annual data on corn are available. Consequently, data on ethanol and corn complement each other for the purpose of the analysis. If we are interested in the effect of ethanol plants on planted corn, then the order in which the data are given suits the purpose. For example, a farmer who needs to decide which crop to grow and how much (around April every year), has enough time to get the ethanol plants' capacities report in his area (February every year), and form his decision based on the report.

This chapter employs the Great Circles method to calculate distances between two coordinates. Calculating the shortest distance between two points on a sphere (a good approximation for distance on the globe), can be done by using the following formula:

$$= ER * ACOS\{COS[RADIANS(90 - Lat_1)] * COS[RADIANS(90 - Lat_2)] + SIN[RADIANS(90 - Lat_1)] * SIN[RADIANS(90 - Lat_2)] * COS[RADIANS(Long_1 - Long_2)]\}$$

Where ER is the earth radius measured in miles. Lat₁ and Lat₂ are the latitudes of the two points of interest. Long₁ and Long₂ are the longitudes of the two points of interest.

Note: In this formula, Lat₁, Lat₂, Long₁, and Long₂ must be entered as decimal degrees (e.g. 45.5 rather than 45:30:00).

2.5 Results

The radius found to minimize the SSE from the non-linear least squares procedure is 286.17 miles (equivalent to $\gamma=0.003494$). The results suggest that the weight of actual ethanol capacity is equal to one in the county centroid and diminishes linearly to zero as the distance between the county centroid and the ethanol plant approaches 286.17 miles. This point is also known as the Zero Effective Distance (ZED) because additional ethanol capacity beyond this point does not affect the production of corn within the county. Table 2 represents the NLS results from the econometric model estimation using a radius of 286.17 miles.

The results show that an ethanol plant increases the level of planted corn nearby. The coefficient of the variable capacity is positive and highly significant. According to the

results, adding an additional million gallons of capacity at the county centroid stimulates another 5.21 acres (with a standard error of 0.68) of planted corn in the county. It means that if a typical 100 million gallon dry mill ethanol plant were built at a county centroid, then the expected increase in the level of planted corn in the same county would be 521 acres. According to planted corn statistics, 521 acres change is economically significant, especially for low-planted corn counties. For instance, either in year 2002 or 2008 approximately half of the counties analyzed planted corn between 0-10,000 acres. Consequently, a change of 521 acres of planted corn which result from building a 100 million gallons ethanol plant will account for an at least 5.21% increase in planted corn in these counties. However, it is important to mention that the majority of ethanol plants are located in areas where corn is abundant and therefore the impact on abundant counties that plant 100,000 or even 200,000 acres of corn will be less significant (0.52% increase and 0.26% increase respectively). For more information on U.S. planted corn by county, see histograms for 2002 and 2008 in Figure 13Figure 14. The results also indicate that the soybeans coefficient, θ , is positive and highly significant. This implies that farmers tend to rotate corn and soybeans.

Using the model estimates, I can calculate the response of the total corn supply from surrounding counties to a siting of a 100 million gallon-capacity ethanol plant. The calculation proceeds from the following formula:

$$= 5.21 \times 100 \times \left(\sum_{i=1}^N 1 - 0.003494 \times Distance_{ij} \right)$$

where 5.21 is the corn acreage effect on county i resulting from an additional million gallons of capacity at county i 's centroid. This effect is multiplied by 100 to represent the change of planted acres of corn by a typical 100 million gallons plant. The term in the large parenthesis discounts the capacity of each county i using the value of 0.003494

and sums the values for all counties. That is to say, for each county within 286.17 miles from plant j , the effect will be weighted by the distance between county i and the plant j using the discount factor $\gamma = 0.003494$. For example, if the 100 million gallon plant was located at the center of one of the counties within radius, then the distance between the plant and that county would equal zero ($D_{ij} = 0$). As a result, the value after discounting for distance for this specific county will be equal to 1, which means the effect of the plant on this county is equivalent to 521 acres of planted corn. In a different example, a county centroid located 200 miles from the ethanol plant will have a lower effect on planted corn. To be precise, the effect of the plant on this county will equal only 157 acres⁴.

The following example applies the above formula for finding the total corn supply effect of an ethanol plant. The plant chosen for this example is Advanced Bioenergy in Fillmore County, Nebraska. The plant has 100 million gallons capacity and uses corn as feedstock. The plant appears for the first time on the RFA annual report in 2008. The total number of counties within 286.17 miles of the plant is 348. Figure 17 demonstrates the 286 radius around the plant's location. The total effect on corn supply according to the formula is 64,623 acres of planted corn in surrounding counties. If we assume each acre yields 150 bushels, then this number is equivalent to about 9.7 million bushels of corn.

In addition to measuring the total corn reaction effect of locating a new ethanol plant, I can also calculate the corn response as a share from the corn needed to produce this additional capacity. Technology enables producers today to produce around 2.7 gallons of ethanol from every bushel of corn in a dry mill process (additional co-products will be produced during the process). In order to produce a million gallons of ethanol, then 370,370 bushels of corn are required⁵. Since the average corn yield in 2008 in the United States is about 150 bushels per acre, the result of a 5.21 acres impact, is an increase in

⁴ $5.21 \times 100 \times (1 - 0.003494 \times 200 \text{ miles})$ equals about 157 acres.

⁵ 1,000,000 gallons divided by 2.7 the technology factor, equals 370,370 bushels.

corn supply for a given county, given an increase of one million gallons of ethanol within the county of 781.5 bushels⁶. The amount of ethanol that can be produced from 781.5 bushels is 2,210 gallons⁷. Therefore, the change in a county's area contributes about 0.21% of the total corn needed for producing an additional one million gallons of capacity⁸. The corn supply contribution of 0.21% is small and declines as the distance between the plant and county increases. However, the results show the impact of an additional capacity on a specific county. As we saw in the previous example on the ethanol plant in Nebraska, there are many counties in a 281.17 mile radius from the plant. That is to say, in order to realize the effect of additional ethanol capacity on planted corn around the plant, I need to use the formula suggested earlier and aggregate corn response of all counties within a 286.17-mile radius of the plant. I can use the results from the previous example to calculate the corn reaction as a share of the corn needed to produce ethanol at the plant. The total corn response effect as calculated is 64,623 acres or around 9.7 million bushels of corn, and in order to produce 100 million gallons of ethanol the plant will have to use about 37 million bushels of corn. If I divide the first by the last, we see that the planted corn reaction effect accounts for about 26% of the plant's feedstock needs. In other words, the plant has a corn deficit of 74% of the corn for production. In order for the plant to operate at more than 26% capacity, it has to compensate for this corn deficit by shifting more corn from other uses or to ship corn from far away. The same calculation of corn response as a share from the corn needed for the plant to run in full capacity is done for all ethanol plants in the dataset. Figure 18 demonstrates the corn deficit histogram for the plants.

This finding is backed up by the findings of another paper that concludes ethanol plants' siting does affect corn prices around the plant (see McNew and Griffith, 2005). As the corn supply reaction due to an ethanol plant siting does not provide the total amount of corn the plant needs, the plant has to compete with other corn users over the available

⁶ 5.21 acres x 150 bushels yield per acre, equals 781.5 bushels.

⁷ 781.5 bushels x 2.7 the technology factor equals 2210 gallons.

⁸ 2210 gallons / 1,000,000 gallons is equal to 0.00211.

corn which in turn causes a price increase. Using bootstrap techniques and a spatial error model, I can account for estimates' uncertainty and spatial autocorrelation.

Table 3 presents the confidence intervals for the radius and the other estimators from the original model (NLS), residual bootstrapping, and block bootstrapping.

Using the residual bootstrap approach (Anselin 1990) I can account for estimates' uncertainty by constructing confidence intervals for them. The computed 90% confidence intervals for the radius, 286 miles, is (210, 389) miles. This confidence interval is constructed from the residual bootstrapping of the non-linear least squares procedure 1,000 times and then using the 5% and 95% percentiles of the empirical distribution. In addition to the confidence intervals of the Zero Effective Distance (ZED) radius, the bootstrapping procedure can be used to calculate the confidence intervals for the coefficients on capacity, lagged corn, and lagged soybeans. The approach is to use the estimators and the standard errors results from the residual bootstrapping procedure to construct t-statistics. Then, I construct confidence intervals using the original estimators (using the 286.17 mile radius) together with its standard errors, and the 5% and 95% percentiles of the empirical distribution of the t-values from the bootstrapping results.

Similarly, the block bootstrap procedure, where spatial blocks (county and its neighbors, Hall 1985) are pulled out, also uses 1,000 resamples and the 5% and 95% percentiles of the empirical distribution to calculate the confidence intervals of the original NLS estimates. The block bootstrap provides information on estimates' uncertainty in the context of spatial autocorrelation. In order to perform a block bootstrap, one needs to decide upon the criteria that defines a county's neighbors. In this chapter I choose distance, however I still need to decide what distance to use. Because it is a matter of discretion, I have decided to cover all reasonable distances and report them. Table 5 shows the confidence intervals of the block bootstrap estimators using different distances to define neighborliness. Figure 15 demonstrates graphically how the confidence interval of the EC radius shrinks when the distance becomes large enough to include all observations in the dataset in one resample. The point where the confidence interval

collapses to one point is around 2,500 miles and the estimates in this case are identical to the NLS estimates. In other words, using a 2,500-mile (or beyond) definition of neighbor counties includes all counties from the original dataset and therefore the block bootstrap's dataset is identical to the dataset used to generate the NLS estimates.

This analysis of changing block bootstrap estimates when the distance definition of neighboring counties changes contributes to the existing bootstrap literature and sheds more light on the subject. The estimators' confidence intervals resulting from the block bootstrap procedure change depending on the neighbors distance definition. In some cases, few of the estimates' confidence intervals are similar to the NLS confidence intervals; however in other instances the estimates are different (for more information, see table 3 and table 5).

The spatial error model uses Maximum Likelihood together with a weight matrix to derive estimates that account for spatial autocorrelation among counties. Two different models employ two kinds of weight matrices; the first is based on the inverse distance between any two counties, and the second (contiguity) includes binary variables that are equal to one if the two counties belong to the same state or zero if they are not. The spatial error model uses the radius result from the NLS estimates and calculates new estimates for the coefficients on capacity, lagged corn, and lagged soybeans. The spatial error estimates using the inverse distance and the contiguity weight matrices are similar to the results of the NLS. However, because the spatial error model accounts for spatial autocorrelation among counties, the t-statistic of the coefficient on capacity and lagged soybeans are smaller but still significant at the one percent level (for details see table 4).

There are several factors that without their involvement, the effect of ethanol industry expansion on planted corn found in this paper could have been larger:

First, the amount of corn used for ethanol production can rise not only from increasing supply but also from corn shifting from other industries. Without shifting corn from

other uses, the demand for additional corn resulting from the ethanol industry would have increased corn prices such that it would be more lucrative for farmers to produce corn at the expense of other crops or to allocate more land to corn production. One example of a corn use shift between industries is corn for feed that shifts toward ethanol production. In practice, the meat production industry is forced to compete with the ethanol industry for corn availability. It is worth mentioning that on the other hand, the meat production industry benefits from Dried Distiller's Grains (DDGs) for feed that results as a co-product in the ethanol production process.

Second, corn is diverted to ethanol production not only from other industries but also from inventories. Even with a corn production increase, the ethanol industry's increased use of corn is reflected in declining ending stocks in the last four years (see table 1). The rapid growth of the ethanol industry in its first years was possible in part due to the U.S. corn stock surplus available at that time. Furthermore, the Renewable Fuels Standard program mandated low production levels of ethanol in the first year but then higher levels in subsequent years. As result, corn stock has a significant role in the feasibility of the RFS program since it is used as a corn supply buffer to bridge between corn supply and demand. Since the establishment of the RFS program and its implementation, U.S. corn ending stock has decreased. Furthermore, the ratio between corn stock and total corn use is expected to be 9.1% for 2009/10, as predicted by the USDA. This ratio level is the lowest level that has been seen since 1995/96 (stock/use ratio under 10% appeared only twice since the year 1973/74). Table 1 shows corn production and consumption and the gap between them for the years 2002 through 2008. For example, the United States ended the 2005/06 marketing year, September 2005-August 2006, with stocks of about 1.967 billion bushels which is enough to produce approximately 5.3 billion gallons of ethanol. As opposed to that, the United States ended the 2007/08 marketing year with only 1.624 billion bushels and a projected 1.145 billion bushels in 2009/10. Without the privilege of using additional corn from the ending stock, corn price would probably

increase and hence lead to a higher effect on planted corn than was observed in the results of this paper.

Lastly, although most of the corn in ethanol production is transported from counties near the plants, there are ethanol producers who ship corn from distances greater than 286 miles. These shipments are more likely to be delivered by rail since truck shipments are less cost effective for long distances.

Another point worth mentioning is that the time dummy variables in the model do not only control for expected corn price but also for corn yield changes over time. The total quantity of corn produced in the United States has increased significantly over the last few years. Table 1 shows the increase in production from marketing year 2002/03 of about 9 billion bushels to more than 13 billion bushels in 2007/08. One major factor for this increase is the rise of corn yield per acre. Table 1 shows an increase in corn yield from about 130 bushels per acre to 150 bushels. As indicated by the USDA, technological improvements such as new seed varieties, fertilizers, pesticides, and machinery together with better production practices such as reduced tillage, irrigation, crop rotations, and pest management systems enabled a higher yield for farmers. Without including time dummy variables in the model, the analysis would have failed to account for corn yield changes over the years. As a result of that, the new effect of ethanol plant siting on planted corn would have been smaller than the effect with the time dummies because higher corn yield requires less planted corn for any given production level.

2.6 Conclusion

Increasing ethanol production is inevitable as mandated by the RFS. Consequently, unless a different feedstock is used, more corn needs to be either produced or diverted from other uses into the ethanol industry. Today, corn production shows signs of

adjustment to meet soaring demand, however with declining corn stocks and increasing ethanol production mandate levels, concerns about the smooth growth of the future corn-based ethanol industry may rise.

The results of this chapter imply that corn supply is positively responding to the changes in demand coming from the ethanol industry. Locating an ethanol plant in a certain area does trigger additional planted corn, especially locally around the plant. The response to an additional million gallons of capacity at the county centroid is 5.21 acres of corn in that county. However, the effect declines linearly to zero as the distance of the county from the plant approaches 286.17 miles. Moreover, the aggregate effect on planted corn is much higher than 5.21 acres as the radius typically includes hundreds of counties around the plant (see section 2.5, Results).

There are many factors that without them the effect of locating an ethanol plant on planted corn, found in this paper, would be larger. These are diversion of corn from other industries, and consumption of U.S. corn stock that is used as a demand and supply buffer. The second RFS mandate requires a production of 10.5 billion gallons of corn-based ethanol for the year 2009 and 15 billion gallons by 2015. It is unclear how the new corn market equilibrium will look when the ethanol production mandate reaches the 15 billion gallon level and stays there for the following years. Assuming ethanol producers will indeed expand their capacity, it will be interesting to rerun this chapter analysis a few years from now and see how the effect of larger ethanol capacity influences the willingness to plant corn and how sustainable higher levels of planted corn will be over time.

Chapter 3: The Effect of Ethanol Plant Siting on Corn Basis

3.1 Introduction

The literature on ethanol plant siting in general and its effect on corn prices in particular is limited. Only one paper has examined the effect of ethanol plant siting on regional corn prices (see McNew and Griffith, 2005). This study investigates this topic using the previous paper as a base while relaxing several of the model assumptions and increasing the dataset size.

As of 2011, corn is still the primary feedstock used in ethanol production in the United States. Understanding this tightening and dual relationship between the ethanol industry and the corn market is crucial for the sustainability of the two industries. Lower corn price regions attract ethanol plants, while the existence of nearby ethanol plants increases local demand for corn and therefore may increase its price. The attractiveness ethanol producers see in low corn price regions is clear and noticeable, whereas the effect of new ethanol plant siting on rising corn demand is the central part of this paper. Ethanol plants are attracted to cheaper corn regions because corn can account for 50-70 percent of ethanol input cost, depending on corn price⁹. Purchasing corn at a lower price can significantly reduce ethanol production cost.

To understand the effect of ethanol industry growth on corn prices, one needs to pay attention to the corn supply reaction to the increasing corn demand that results from the growing ethanol industry. The main driver for the accelerated ethanol production is the

⁹ See “Guide for Evaluating the Requirements of Ethanol Plants”, The Clean Fuels Development Coalition, The Nebraska Ethanol Board and USDA.

Renewable Fuel Standard (RFS). The RFS mandates require gradually increasing ethanol production in the United States over several years. The second RFS sets a total U.S. ethanol production requirement of 36 billion gallons, where 15 billion gallons out of the total will be produced from corn by the year 2022 (see Figure 7). For more details on corn supply levels and the corn consumed by the ethanol industry between the years 2002 and 2008, see table 1. Figure 5 along with its table demonstrate the change in U.S. ethanol capacity between the years 2002 and 2008.

If corn supply fails to catch up with the increasing corn demand resulting from the mandate, the likely outcome is higher corn prices. Higher corn prices raise farmers' revenue and therefore provide an incentive for farmers to allocate more land and other resources for growing corn at the expense of growing other crops such soybeans and wheat. Consequently, the quantities produced from soybeans and wheat decrease and their prices increase along with corn price. An alternative for allocating more land for corn production besides shifting land from other crops can be dedicating additional lands that are not currently used for crop production. According to the USDA, cropland used as pasture, reduced fallow, and acreage returning to production from expiring Conservation Reserve Program contracts are all land uses that were converted to corn production due to the increase in corn price. However, bringing additional land into corn production is likely to occur after a continuous period of high corn prices and not just a temporary price increase.

The results in Fatal (2011a), which investigates the impact of ethanol plant location on the supply of corn around the plant, implies that corn price will not increase to the full extent of the demand increase because corn supply will increase to meet the new demand and mitigate some of the price increase. As previous studies show (Fatal, 2011b and the paper by Wilcox, English and Stewart, 2008), proximity to input markets is the most important determinant for locating an ethanol plant. This way, ethanol plants are not only able to reduce input purchasing cost but also reduce corn shipping costs to the plant.

Moreover, the smaller the distance traveled from corn source to the plant, the smaller the uncertainty of having corn in time for production. Intensive corn production areas such as the Corn Belt¹⁰ (see Figure 19) are likely to attract ethanol plant siting because corn is abundant and its price in this region is lower than in other areas in the United States. The locations of ethanol plants in 2009 are displayed in Figure 9. It is clear from this figure that the majority of ethanol plant producers decided to locate their production plants in the Corn Belt, which is a saturated corn area (see Figure 10) with cheaper corn price (see Figure 11).

3.1.1 Literature Review

There are only a few studies investigating the implications of ethanol plant siting, whereas only one study examines the effect of plant siting on corn price around the plant. The study examined the effect of placing an ethanol plant on grain prices by using 12 ethanol plants that opened between the years 2001 and 2002 (McNew and Griffith, 2005). The study results indicate that there is a positive price effect; however this price impact is not uniform around the plant. In this study the authors differentiate between upstream and downstream corn markets relative to the new ethanol plant location. The upstream and downstream concepts are based on the idea that corn flows spatially from different markets to a corn terminal market (called downstream). Consequently, when an ethanol plant is located between the market and the terminal, then the market is considered to be upstream to the plant (or the plant is downstream to the market). On the contrary, when the market is between the terminal and the new ethanol plant, the market is considered to be downstream to the plant (or the plant is upstream to the market).

¹⁰ The Corn Belt region mainly includes the states of Iowa, Indiana, Illinois, and Ohio. Also included are, parts of South Dakota, North Dakota, Nebraska, Kansas, Minnesota, Wisconsin, Michigan, Missouri, and Kentucky.

The following illustration (taken from McNew and Griffith, 2005) demonstrates the effect of placing a new ethanol plant on the corn spatial price surface.

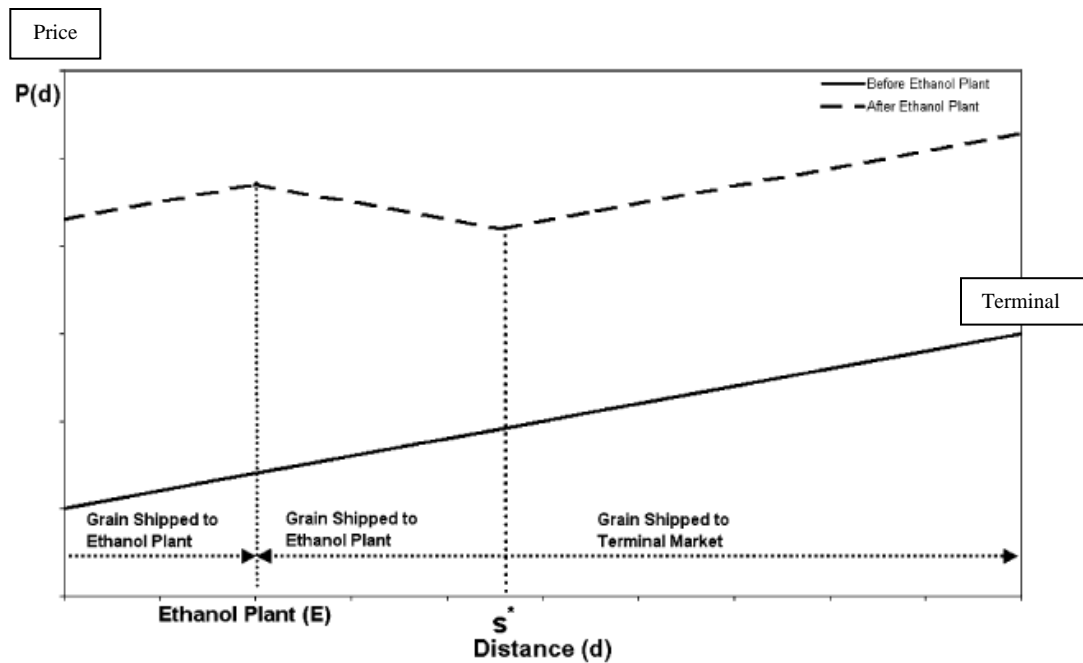


Figure 1. Ethanol Plant Siting Impact on Spatial Corn Price Surface (McNew and Griffith, 2005)

Assume there is one demand center, called Terminal, for the grain that is located in the figure at the right end of the distance segment. If we assume corn is uniformly produced along the line segment and that the total corn production is fixed, then the solid line represents the price received by producers along the line segments. The net price producers receive is discounted due to the cost of shipping and increases continuously as producers are closer to the terminal. When a new ethanol plant is located along this line segment (point E), the plant raises corn demand locally and changes corn trading patterns that existed before the plant existed. The corn price curve not only changes its shape from a straight line into a kinked curve, but also shifts upward.

The change in corn trading pattern can be divided into three parts. First, producers between the point S^* and the terminal keep shipping corn only to the terminal, however they receive a higher corn price than without the new plant. That is because corn shipped to the new ethanol plant reduces the amount of corn shipped to the terminal. The benefit of producers shipping corn to the plant is even higher due to the additional savings in transportation costs. Transportation cost savings will differ among producers depending on their location and their distance to the plant. Producers located upstream to the plant (to the left of point E) will have greater transportation savings. This savings will be identical to all upstream producers regardless of the distance to the plant. Because all producers ship to the same terminal, the shipping distance is reduced for upstream producers by the same amount (the distance between the ethanol plant, point E, and the terminal). The third region on the distance segment line is between the point E and point S^* . In this segment producers ship corn to the plant but their net price received decreases as distance to the plant increases.

The study I offer in this paper provides an alternative model to the one introduced in McNew and Griffith. The new model relaxes some of the assumptions used and also employs a larger and more recent data (see section 3.2, The Theoretical Model).

Ethanol plant siting not only may affect corn price around the plant but corn supply as well. The paper by Fatal (2011a) investigates how regional ethanol plant capacity affects corn supply near the plant. The study is based on a county-level analysis of the 48 contiguous states for the years 2002 through 2008. The empirical analysis uses a non-linear least squares (NLS) model for estimating the key parameters. The analysis accounts for spatial autocorrelation by employing a spatial error model. The results indicate that locating an ethanol plant in a county stimulates additional acres of planted corn within a 286-mile radius around the plant. The effect of an additional one million gallons of annual ethanol capacity in a county is estimated to increase planted corn by

5.21 acres in the county in which the plant is located. This effect diminishes linearly to zero as the distance between the plant and other counties approaches 286 miles.

3.1.2 Study Benefits

Understanding how ethanol plant siting affects corn prices around the ethanol plant is important for many parties. Knowing the change in the price surface in the plant's region once the new ethanol plant is sited can provide beneficial information to an ethanol producer. Because lower corn prices are crucial for maintaining lower production costs, having more information on future corn prices has a large impact on sustainable profitability and the existence of the plant.

The results from this chapter can also help U.S. policy makers understand the implications of biofuel policy, such as the Renewable Fuel Standard, on corn prices. Understanding the dual relationship between ethanol and agriculture industries is vital. Additionally, policy makers will be able to evaluate the effect of ethanol industry growth on farmers and vice versa. The following examples demonstrate how U.S. policy makers can benefit from the results of this paper. First, as the ethanol industry expands, there is a need to ensure that enough corn will be available in order to lower its price and to support industry growth. Unless a different feedstock can be found to commercially replace corn (cellulosic ethanol for instance), insufficiency can lead to ethanol production disruptions and together with higher corn prices industry growth may be constrained. As a result, plant profitability will be affected. In a more extreme case, where corn prices increase can offset plant profits or lack of corn can cause production disruptions, the result may cause a plant to go out of business. In order to promote viable growth in the ethanol industry, policy makers need to have information about future corn prices besides what are corn prices today.

Second, having more information on how ethanol industry expansion affects corn prices can provide insights into future farmers' revenue. This information can assist policy makers in adjusting government agriculture programs so that they can better achieve their goals. A good example is the role of agricultural subsidy programs. Increasing corn prices, where other variables such as corn's production cost stay constant, implies increases in farmers' total revenue. Significant changes in farmers' revenue can cause old government support program to be redundant or unsuitable.

Other parties who may benefit from the paper's results include ethanol industry investors and lenders, farmers who produce corn or buy Dried Distiller's Grains (DDGs), and ethanol buyers.

3.2 The Theoretical Model

To investigate the effect of ethanol plant siting on the corn price surface around the new plant, there is a need to employ two key variables that represent both the ethanol industry and the corn market. The variable associated with the ethanol industry should be an ethanol plant indicator that measures the change in the surrounding ethanol plants around any given corn market. The variable linked to the corn market is corn price for different corn markets throughout the 48 contiguous states.

Because ethanol plants vary by their total production capacity, plants' corn needs are different. A good candidate for representing nearby ethanol plants is the Total Ethanol Production Capacity variable. This variable is measured as the sum of capacity for all plants within a certain radius distance from the relevant corn market (the determination of the radius used to calculate total ethanol capacity is explained later). The variable Total Ethanol Production Capacity changes over time as ethanol plants are added or subtracted in the area in and around the market. The variable also captures plant capacity

expansions. The location of ethanol plants relative to corn markets may change the magnitude of the plants' impact on the corn markets due to the change in transportation costs.

In order to take into consideration the location of ethanol plants relative to corn markets and major corn terminals, there is a need to categorize plants' capacities according to the upstream/downstream classification introduced in the study of McNew and Griffith (2005).

In this paper I classify upstream and downstream ethanol capacity by comparing corn prices at the plant and the market before the plant opens. If the corn price in the market is higher than the plant's price, then this market is downstream of the plant (or the plant is upstream of the market). On the contrary, if the corn price in the market is lower than the plant's price, then this market is upstream of the plant (or the plant is downstream of the market). There is one problem with the classification method. The plant's price is not observable prior to date the plant opened. However, the use of a market price closest to the plant will be a reasonable proxy. Figure 20 illustrates the distance distribution of all 96 plants to their closest corn markets. The figure indicates that 50% of the proxy markets are within two miles from the plant location and 74% within 4 miles.

Alternative measures were considered for representing corn in the model. First is the choice between using corn prices or corn basis. Basis is the difference between the corn cash price and the corn futures price (cash – futures), for the time, place and quality where delivery actually occurs. Basis prices control for changes in supply and demand nationally while indicating any changes that result from local demand and supply forces. Consequently, I choose to use basis as it better reflects the effect of siting an ethanol plant on local corn markets. Second, I need to choose whether to use corn transaction price or plants' bid price. Because corn transaction price is not accessible for me, I use plants' bid price which is the price the plant is willing to pay producers for corn at a

certain quality at the plants' gate. Assuming the grains meet the quality requirement of the ethanol plant, the bid price should serve as a floor price for the corn producers as the price paid may increase due to negotiations between the producer and the plant.

The paper investigating ethanol plant siting on corn prices by McNew and Griffith provides a major contribution to the literature on this topic. However, the study can be improved by relaxing some of the assumptions used and also utilizing a larger dataset. The following describe the differences in more details.

First, as opposed to McNew and Griffith who ignore plant operation scale (capacity) in the estimation, I choose to use plants' capacities rather than just whether the plant was operational or not. Plants with different production capacities have different corn needs for ethanol production. A larger ethanol plant is expected to have a higher effect on local corn demand and on corn prices. Second, the authors assumed the distance of the effect of a new ethanol plant on corn prices. The authors used a 150-mile square area centered on the ethanol plant when evaluating price effect on corn markets. There are two problems with the author's approach. The first is the issue with making the assumption of 150-mile distance effect. The decision about the area around the plant is ad hoc and therefore subject to criticism. I suggest letting the data tell the appropriate distance effect by using non-linear least squares (see more details later in this section).

The second problem is with the shape of the area surrounding the plant. In order to measure the effect of plants on the surrounding area, I suggest using a circle instead of a square. Using a radius will assure equal distance from the plant to any direction.

Third, in their model the authors have used a cross section analysis that includes only 12 plants that were open between the years 2001 and 2002. I'm able to analyze a more detailed, updated and comprehensive panel dataset on 96 ethanol plant entries between the years 2002 and 2008. Fourth, the approach of the authors was to use the ethanol plant

location as a base, and compare changes in price in surrounding markets. Alternately, my approach uses each corn market as a base along with the total ethanol capacity surrounding it. Doing so will enable me to investigate the impact of one additional unit of ethanol capacity on corn price as well as the aggregate effect of all plants within radius for the relevant market.

The following illustration inverts the model of McNew and Griffith in section 3.1.1 by fixing the market point while allowing ethanol capacity to be either upstream or downstream.

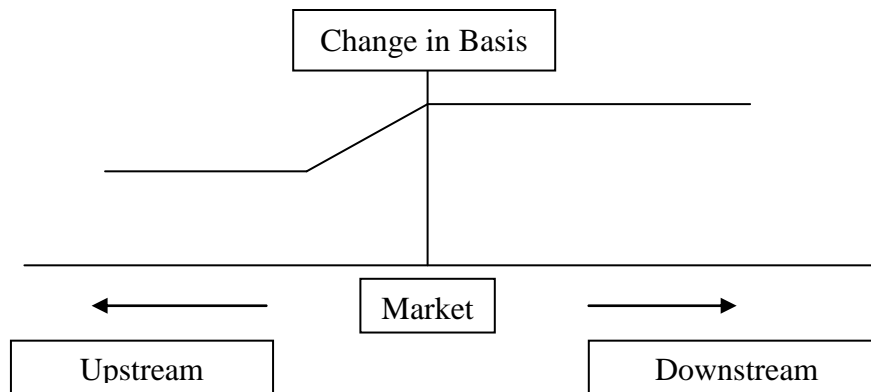


Figure 2. Ethanol Plant Capacity Impact on Spatial Corn Basis Surface

The equivalency of the illustration above to the figure in the model of McNew and Griffith in section 3.1.1 can be explained by the following example. In the illustration above, upstream corn producers to the plant reduce shipping cost by the same amount regardless of their distance to the plant (the change in corn basis is the same). Because the idea of upstream markets to the plant is conceptually equivalent to the idea of plants downstream to the market, then when I fix the corn market and allow the ethanol capacity to change, the effect on corn basis will be identical to all plant capacities added downstream to the market (shown in the above figure to the right of the market). Similarly, because downstream corn producers to the plant benefit from the transportation

cost saving up to a certain point due to the plant siting, together with the fact that the idea that downstream markets to the plant are equivalent to the idea of plants upstream to the market, then the effect on corn basis decreases up to a certain point and stays constant afterwards. Note, the effect on basis is identical for both upstream and downstream capacities at the market point. Additionally, the effect on corn basis stays positive throughout the figure for both upstream and downstream capacities due to the reduced amount of corn going to the terminal market also assumed by McNew and Griffith.

Given measures for the ethanol industry and corn price, I start with the following simple model:

Equation 4 The Effect of Ethanol Capacity on Basis Price

$$B_{it} = \alpha + \beta \sum_{j=1}^N C_{jt} + \varepsilon_{it}$$

where:

B_{it} = corn basis for market i in year t , measured in cents,

C_{jt} = ethanol production capacity of nearby plant j in year t , measured in annual million gallons per year (N plants),

ε_{it} = error term of the model for market i in year t .

The summation of all C_j 's provides the total ethanol production capacity of all nearby plants from market i . Therefore the interpretation of the coefficient β is the effect of a unit increase in nearby ethanol capacity on corn basis. Figure 15 demonstrates which ethanol plants will be considered as nearby plants. That is to say, these are the ethanol plants within a specific radius distance from a given corn market.

Equation 4 is a simple and straightforward model, and does not reflect other important considerations. In particular, it does not capture that basis decreases smoothly with distance from the plant, and not discontinuously. As you get further away from the ethanol plant, you would expect the effect of ethanol plants on corn basis to weaken. For instance, an ethanol plant with 100 million gallons 10 miles away from the corn market should have a greater impact on corn basis than the same plant 50 miles away. The model can account for this effect by adding another term based on the distance between ethanol plant j to market i (D_{ij}). Total ethanol production capacity weighted by the distance between the corn market and the ethanol plant will be called Effective Capacity (EC) in this paper. The capacity weight will equal one when D_{ij} is equal to zero and will diminish to zero as D_{ij} increases, until the point where $EC=0$ (also known as Zero Effective Distance, or ZED). Equation 5 suggests an improved model that incorporates the effect of distance between the ethanol plants and the corn market on Effective Capacity.

Equation 5 The Effect of Ethanol Capacity on Corn Basis Using Effective Capacity

$$B_{it} = \alpha + \beta \sum_{j=1}^N \text{Max}(1 - \gamma D_{ij}, 0) C_{jt} + \varepsilon_{it}$$

where D_{ij} is the distance between market i and plant j measured in miles. The value of γ is the discount factor by which actual capacity (C_{jt}) is weighted by distance D_{ij} . The value of γ will be determined directly from the radius distance¹¹ that will be chosen to calculate the total ethanol production capacity around the market. Figure 16 shows how ethanol plant capacity is discounted by distance.

¹¹ $EC = 0$ where $1 - \gamma D = 0$, which implies that $\gamma = 1/D$.

In order to carry out the analysis and calculate the total ethanol production capacity around the market, one needs to determine the radius distance. The larger the radius, the higher total ethanol production capacity will be since the result from the calculation will contain more plants. The decision about what radius to use for the analysis is not an easy task. McNew and Griffith found a positive corn price impact up to 68 miles away from the new plant. The decision about the right radius can be a matter of discretion and subject to critique. I choose to let the data tell what should be the right radius by employing a non-linear least squares approach using different radii. By running the model many times with different radii, I can compare the fitness of the model to the data for each radius. The radius specification that provides us with the best fitness will be the chosen radius. In order to decide what makes a better fitness, I need to define the criterion used to base our decision. The criterion for choosing the correct radius will be the value of sum of square errors (SSE) that result from the model. I will choose the radius specification with the lowest SSE value. Once the radius is determined, the value of γ will be determined by $\gamma = 1/\text{radius}$.

The model in equation 5 is more comprehensive and therefore more realistic but still incomplete. As mentioned earlier, the locations of ethanol plants and corn markets relative to the terminal markets may be important and therefore should be accounted for. The effect of new ethanol plant on the basis surface around the plant may differ for new upstream versus downstream capacity. The following econometric model accounts for this distinction.

3.3 Econometric Model

The following model uses a panel dataset and includes market and time fixed effects.

$$B_{it} = \sum_{k=2003}^{2008} \omega_k D_k + \sum_{i=1}^{425} \theta_i M_i + \delta \sum_{j=1}^N \{ \phi_{ij} (1 - \gamma_u D_{ij}) + (1 - \phi_{ij}) (1 - \gamma_d D_{ij}) \} C_{jt} + \varepsilon_{it}$$

where:

$i = 1, 2, \dots, 425$ (corn markets),

$t = 2002, 2003, 2008$ (seven years),

B_{it} = basis corn price February average for market i in year t , measured in cents,

D_k = time fixed effects, $k = 2003, 2004, \dots, 2008$,

M_i = market fixed effects,

D_{ij} = distance between market i and plant j , measured in miles,

N = the total number of ethanol plants within specified radius,

ϕ_{ij} = dummy indicator, when equal to one indicates upstream capacity, and when equal to zero indicates downstream capacity of plant j from market i ,

C_{jt} = ethanol production capacity of plant j from market i in year t , measured in annual million gallons,

γ_u = upstream ethanol capacity discount factor,

γ_d = downstream ethanol capacity discount factor,

ε_{it} = idiosyncratic error,

$\text{Var}(\varepsilon_{it}) = \sigma^2$ is the variance of the error term of the model.

The role of the time dummy variables in this model is to control for variables affecting corn basis that are excluded from the model and that change over time but not by county. The dummy variables, M1-M425, represent market fixed effects and their purpose is to control for heterogeneity among markets. Additionally, the summation component provides the total effective ethanol production capacity of all plants within the appropriate radius. That is to say, the sum of the weighted ethanol plant capacity around market i . The sign of the coefficient δ is expected to be positive as the main assumption is that the location of a new ethanol plant will increase corn basis around the plant region. Within the summation term I include the total effective ethanol capacity, however I distinguish between upstream and downstream capacities using the dummy indicator, ϕ_{ij} . Moreover, I use different weights for scaling upstream and downstream capacities by using γ_u and γ_d .

Two specifications of this econometric model are used. The first specification allows the weights for upstream and downstream (γ_u and γ_d) capacities to be different. The second specification restrict both weights to be the same ($\gamma_u = \gamma_d$). In both specifications the basis price effect is forced to be the same at the plant location.

The following illustrates the upstream/downstream basis surface from the market point. The solid line represents the unrestricted model whereas the basis slopes are allowed to be different from each other (γ_u and γ_d can be different). In other words, the rate in which the capacity effect of the ethanol plant diminishes to zero can be different for upstream then downstream capacity. The dotted line stands for the restricted model where the slopes are forced to be the same ($\gamma_u = \gamma_d$). Note, both models force the effect to be the same at the market location.

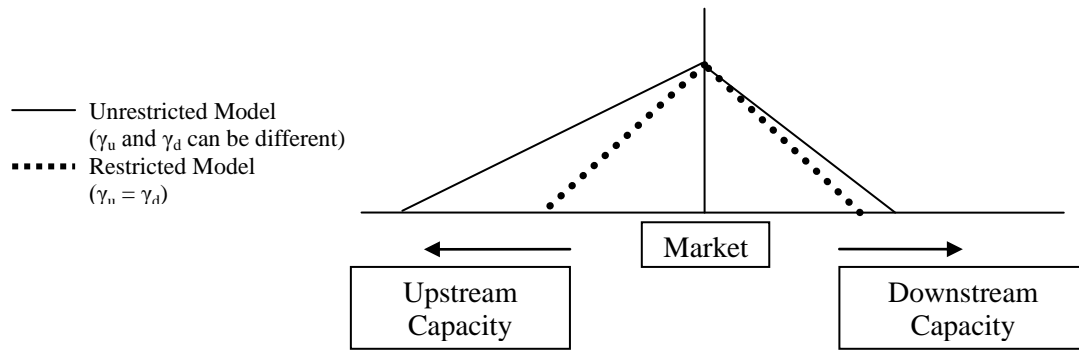


Figure 3. Basis Surface from Market Point (Restricted/Unrestricted Models)

Because corn markets may be geographic neighbors, they are likely to have similarities, and thus the standard errors of this study can be underestimated. This problem is known in the literature as spatial autocorrelation. That is to say, for every given year, any two neighbor corn markets are likely to have positive correlation in the error term $E(\epsilon_{it}\epsilon_{jt}) > 0$. There are a few ways to account for spatial autocorrelation. Although they are not presented here, one way is to calculate the new standard errors using a block bootstrapping technique. This approach resamples observations with replacement from the original dataset in a block form. For each observation (corn market) withdrawn from the data, the spatial block (the corn market and its market neighbors) is pulled out (Hall 1985). In this way, the bootstrapping will incorporate spatial autocorrelation into the standard errors of the estimators and modify their values accordingly. Note, in order to perform a block bootstrap, one needs to decide upon the criterion that defines a market's neighbors. Another way to account for spatial autocorrelation is to use an explicitly spatial error model. This approach uses Maximum Likelihood together with a weight matrix to derive estimates that account for spatial autocorrelation. The most common weight matrices are inverse distance and contiguity. More details can be found in Fatal (2011a).

3.4 Data

Data on ethanol plants for the years 2002 through 2008 are taken from the RFA (Renewable Fuel Association - <http://www.ethanolrfa.org/>). The dataset is built on seven annual reports (every February) for the years 2002 through 2008 and includes information on 143 plants (see appendix 1 for the full plant list) that produced ethanol during the years of analysis. The data variables available are plants' names; feedstock used in production (the paper used only plants with corn as a feedstock); and nameplate capacity (the maximum production level the plant is permitted to produce). Several ethanol firms had multiple plants in the dataset and only one aggregate name plate capacity for all of them. Therefore, capacities for individual plants had to be recovered by contacting the firms or by using their internet web sites. Location of U.S. ethanol plants is based on the information from the RFA and Ethanol Producer Magazine (<http://www.ethanolproducer.com/>). Latitude and Longitude coordinates of the plants had to be collected separately using the plants' addresses.

Data on corn basis were made available by Cash Grain Bids, which is a private company supplying data and analysis for grain price intelligence. The corn basis provided is an average basis for every February for the years of analysis. The corn basis dataset includes a balanced panel of 425 corn markets between the years 2002 and 2008. Figure 21 shows the geographical locations of these markets.

This chapter employs the Great Circles method to calculate distances between two coordinates. Calculating the shortest distance between two points on a sphere (a good approximation for distance on the globe), can be done by using the following formula:

$$= ER * ACOS\{COS[RADIANS(90 - Lat_1)] * COS[RADIANS(90 - Lat_2)] + SIN[RADIANS(90 - Lat_1)] * SIN[RADIANS(90 - Lat_2)] * COS[RADIANS(Long_1 - Long_2)]\}$$

Where ER is the earth radius measured in miles. Lat₁ and Lat₂ are the latitudes of the two points of interest. Long₁ and Long₂ are the longitudes of the two points of interest.

Note: In this formula, Lat₁, Lat₂, Long₁, and Long₂ must be entered as decimal degrees (e.g. 45.5 rather than 45:30:00).

3.5 Results

The results for the econometric model using a non-linear least squares procedure are shown in table 6. The results include restricted and non-restricted versions for the basis slope from the market point. The restricted version forces the upstream and downstream slopes to be the same ($\gamma_u = \gamma_d$), while the non-restricted version allows them to be different.

The results from the restricted model indicate that there is a positive effect of ethanol plant siting on the corn basis surface around the plant. The effect on basis equals 0.0193 cents per bushel for every additional annual million gallons at the plant location. For example, placing a typical 100 million gallons ethanol plant at the market location will increase corn basis by 1.93 cents per bushel. The effect found is highly significant and diminishes linearly to zero as the distance between the market and the ethanol plant reaches 103.19 miles.

In practice, it is likely that there is more than one ethanol plant within 103.19 miles with different distances from the market. Consequently, in order to understand the total effect of all ethanol plants on a single corn market, one needs to aggregate the weighted effects (effective capacities) of all ethanol plants within a 103.19 radius from the market of interest. Using the model radius estimate, I can calculate the value of γ , the capacity discount factor, by dividing 1 by the radius, 103.19 (0.0097). Then I use the value of γ to weight the ethanol capacities around the market utilizing the information I have on distances between any given market and each ethanol plant. Table 7 shows the summary statistic of the results. For more details on the distance calculation methodology, see appendix 1.

The results from the unrestricted model are displayed in table 6. Ethanol plant siting has a positive effect on the basis surface around the plant. The effect on basis found equals 0.0189 cents per bushel for every additional annual million gallons at the plant location. The effect found is highly significant and diminishes linearly to zero as the distance between the market and the ethanol plant reaches 101.47 miles for upstream capacity and 107.57 for downstream capacity. The results from both specifications, from the restricted and unrestricted models, are very similar in term of economic effect. The estimates for the effects of ethanol plant siting on corn basis as well as the radius found are close in percentage terms. The capacity effect on basis is slightly higher in the restricted model (2% difference), whereas the radius of 103.19 miles falls in between the narrow band of the two radii found in the unrestricted model (101.47 miles for upstream and 107.57 miles for downstream). This similarity of the results for the two specifications suggests that the distinction between upstream and downstream capacity does not play a major role in determining the effect of ethanol plant siting on corn basis. This outcome is in conflict with the results of McNew and Griffith, who found downstream and upstream market effects to be different.

Because it is not possible to calculate confidence intervals or standard errors of either γ or the radius from the restricted model specification, there is a need to develop a complementary methodology for providing this missing part. The suggested approach for finding the confidence intervals includes a resampling technique with replacement (bootstrapping) of the residuals from the estimated non-linear least squares model. The following provides more details on the bootstrapping technique. The 90% confidence interval found for the radius this way is (82.34, 127.27) miles.

Let $e_t = [e_{1t} \ e_{2t} \ \dots \ e_{nt}]'$

be the $(n \times 1)$ residual vector from the model, where $t=2,3 \dots T$ and

e_t^r be the resampled with replacement version of the vector e_t .

Now, I can reconstruct the dependent variable (Y) using the followings:

$$Y_2^r = X\beta + e_2^r$$

$$Y_3^r = X\beta + e_3^r$$

$$Y_4^r = X\beta + e_4^r$$

$$Y_5^r = X\beta + e_5^r$$

$$Y_6^r = X\beta + e_6^r$$

$$Y_7^r = X\beta + e_7^r$$

$$Y = [Y_2^r \ \dots \ Y_7^r]$$

Where X is the matrix of all explanatory variables and β is the non-linear least squares estimator from the actual data.

Comparing the radius result from this study with the finding in the paper of Fatal (2011a), which examines the effect of ethanol plant siting on corn acreage around the plant, can provide useful insights on the difference between the spatial effects of new ethanol plant

siting on corn price versus corn acreage. The hypothesis is that the radius effect on corn price is equal or greater than the radius on corn acreage. The logic behind the hypothesis is that small price effects (at the edge of the radius circle) will not necessarily stimulate new corn acreage. In other words, the price effect is too small to produce any additional corn by producers beyond that which was otherwise produced. The following figure illustrates an example for a larger price radius effect.

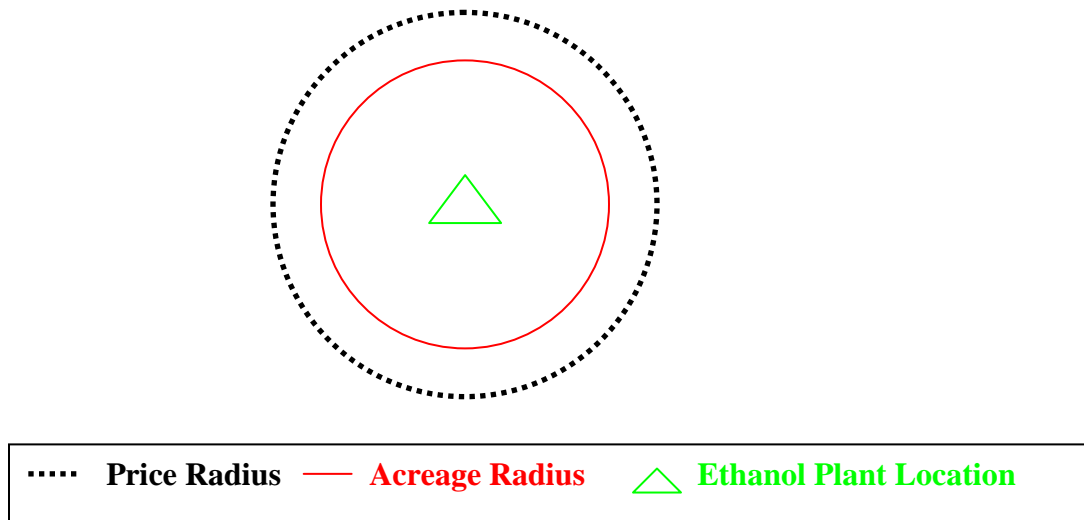


Figure 4. Radii Comparison - Corn Acreage and Basis

In this paper, the radius for the effect of ethanol plant location on corn basis was found to be 103.19 miles from the plant with a 90% confidence interval of (82.34, 127.27). In Fatal (2011a), the radius for the effect of ethanol plant siting on corn acreage was 286 miles with a 90% confidence interval of (209.83, 389.1). Both 90% confidence intervals are produced using a residual bootstrap procedure with 1,000 iterations. The comparison of the radii reject the hypothesis that corn basis radius is equal or greater than the acreage radius. Not only are the estimates different, but the confidence intervals from both studies do not overlap.

One possible explanation for the difference between the quantity and price results comes from comparing the quality and spatial precision of the data. The price data analyzed in the present chapter have precise longitude and latitude coordinates--we know where the corn markets are. In contrast, the corn acreage data analyzed in Fatal (2011a) are spatially aggregated in the sense that all acreage in a county is treated as though it were located at the county centroid. Thus, the imprecision in the dependent acreage variable could result in small, and distant, effects being less precisely measured, resulting in larger measured radii of effects for corn acreage than for corn price. In addition to this explanation, different econometric models in both papers may have a significant input to the difference. This paper uses upstream and downstream variables whereas Fatal (2011a) does not.

3.6 Conclusion

This paper examines the effect of ethanol plant siting on corn basis at various market locations. In contrast with previous literature, the study accounts for ethanol plant scale by incorporating plants' capacities into the econometric model. The model utilizes a non-linear least squares approach to estimate the radius distance of the effect. Additionally, the model distinguishes between upstream and downstream plants from corn markets.

The results of this study indicate that siting an ethanol plant triggers a positive corn basis effect around the plant. The effect on basis equals 0.0193 cents per bushel for every additional annual million gallons at the plant location. The effect found diminishes linearly to zero as the distance between the corn market and the ethanol plant reaches 103.19 miles. In reality it is likely to have market proximity to multiple ethanol plants within a radius of 103 miles, therefore there is a need to aggregate the effects from all plants using the results of this paper. The aggregate effect depends on the market and the year. The maximum effect across markets is 13 cents per bushel. For details, see table 7.

The result also suggest that when letting the data reveal the true radius for the effect of ethanol plant on basis, the distinction between upstream and downstream capacities does not change the estimates significantly. The results obtained from the restricted and the unrestricted models (that distinguishes between upstream and downstream capacities) were similar.

Chapter 4: The Ethanol Industry – Location Entry, and Plant Capacity

4.1 Introduction

As result of U.S. energy policy changes in recent years, the ethanol industry growth rate has accelerated. Due to the Renewable Fuel Standard (RFS), together with new ethanol producers' incentives and the banning of MTBE, additional ethanol plants emerged to increase the United States' ethanol production capacity. Table 8 shows the geographic distribution of ethanol plants at the county level in the United States between the years 2002 and 2008. The growth of the ethanol industry motivates questions of how new ethanol producers make decisions with regards to plant location and plant capacity. Answering these questions should provide valuable information for both policy makers and for current and prospective ethanol producers.

For instance, policy makers will be able to understand the significance and importance of the different factors for locating and sizing a new ethanol plant. The determinants of new ethanol plant locations and sizes can be important when making policy decisions such as those related to rural economic development. For example, if policy makers are interested in increasing the employment or tax base in a certain region, then it will be valuable to know how to influence new ethanol plants to locate their facility in that specific region. Furthermore, acquiring more information on a young growing industry such as the ethanol industry and learning about it can help policy makers promote the sustainability of this industry.

Additionally, firms considering building a new ethanol plant can benefit from the results of this paper. Knowing the right place to locate a new ethanol plant can minimize production costs and make operations more efficient and sustainable. Moreover, the results from this paper can help new entrants determine the optimal plant capacity for their location. Current ethanol producers can benefit from the same information. Knowing the different likelihoods for new entrants in the same region allows them to better position themselves for future competition. Other parties who may benefit from the paper's results include ethanol industry investors and lenders, farmers who produce corn or buy Dried Distiller's Grains (DDGs), and ethanol buyers.

The determinants of new ethanol plant siting were studied previously by Lambert et al. (2008) and also by Sarmiento and Wilson (2007). In the former paper, the authors use a Probit model to analyze the investment activity of ethanol plants at the county level between the years 2000 and 2007. The authors explain location decisions mainly by using geographic and demographic location determinants. The data for these determinants come from a single year, 2000. In the later paper, the authors use a Logit model and a spatial correlation technique. The shortcoming of both of these papers is that they consider ethanol plant entry to each county independently (by using Probit and Logit models). In other words, the authors treat each plant's location decision (county) independently of other counties. So for instance, if the plant has 3,000 location possibilities, then the plant has to make 3,000 independent location decisions. In practice however, ethanol producers make a single plant location decision considering all possible counties simultaneously. In order to make the analysis more realistic, I choose to use a Multinomial Logit model that accounts for the multiple choices that ethanol producers face.

As comparison to the location decision, little is known about producers' capacity decisions. Capacity decisions for new ethanol plants will determine the plants' economic activity such as the level of corn procurement to fulfill the plants' needs, the number of

jobs the plants create, and the survival of the plants. Understanding plants' capacity decision is important not only by itself but also to understand new ethanol plant location decisions. Ethanol producers make location and capacity decisions simultaneously, and these two decisions are likely to affect each other. For instance, a producer considering a large capacity plant would have to carefully choose the plant location because a large amount of corn would be needed to utilize the plant's large capacity. The effect can also go the other way. When a producer decides to locate an ethanol plant in a certain region, the plant capacity should be in line with the location characteristics such that production costs, especially transportation costs of inputs and outputs, are minimized.

The main contribution of this study is to explain the location decisions of ethanol producers in the United States as well as to develop the first model for studying plant capacity decisions. The ideal modeling approach would account for both decisions simultaneously. Because joint decision model is complex, the two decisions are modeled separately.

To model the location decisions, I use a panel dataset that accounts for the dynamics of the model's variables, while allowing multiple location choices of market entry using a Multinomial Logit Model. As opposed to the previous papers, which examine each possible location one at a time, the Multinomial Logit model is used to simultaneously take into consideration the multiple location choices ethanol producers face when making a plant's location decisions. The approach used for modeling ethanol plant capacity decisions is a Random Effects Tobit Model, which accounts for both observed as well as unobserved determinants.

The main results of this paper indicate that for both location and capacity decisions, the most important factors are corn availability near the plant, the existence of previous competitors in the county, and the market size for Dried Distiller's Grains (DDGs) in the county where the plant is located (the market size is determined by the number of cattle

within the county). Additionally, using the estimates from the location decision model I simulate what would be the spread of ethanol plants across the United States if there was no MTBE ban. The simulation results reveal that two states from the Corn Belt, Iowa and Minnesota, lose each one ethanol plant entry while Texas gain two plant entries (see table 13). Furthermore, I conduct a simulation using the estimates from the Random Effects Tobit model to predict the capacity levels for the plants from the location simulation given that there is no MTBE ban. The results from this simulation indicate that without accounting for the MTBE ban, plant capacities would be 7.5% lower on average.

The rest of the chapter is organized as follows. In Section 4.2, I provide detailed information on the determinants of location and capacity decisions. The empirical strategy is presented in Section 4.3. Section 4.4 introduces the data. In Section 4.5, the estimation and simulation results are discussed, and Section 4.6 concludes.

4.2 Location and Capacity Determinants of Ethanol Plants

Producer location decisions as well as plant capacity decisions can be based on many determinants. Some determinants have a direct impact on producers' profits. For instance, input costs such as prices of corn, electricity, and labor. Federal and state tax incentives are assumed to affect the location decision of ethanol producers because these incentives translate into producer profits. Other variables that indirectly affect producers' profit are MTBE bans and competition by other regional ethanol plants. These two factors change the demand for the ethanol produced by each plant. An MTBE ban increases the demand for ethanol because ethanol becomes the first choice for a MTBE substitute, while competition among plants reduces the ethanol sales price and also increases the price paid for inputs such as corn. Other location determinants include: an accessible transportation network such as railroads, highways, and rivers in order to

ship input and output efficiently, proximity to energy sources, farm product warehousing for Dried Distiller's Grains (DDGs), labor skills diversity, and existing infrastructure for water supply and water treatment. The rest of this section discusses these determinants and others in more detail. Figure 23 through Figure 26 show the cost, revenue, and profitability of ethanol producers between the years 2005 and 2009.

4.2.1 Input Markets and Operation Costs

The cost of ethanol production is composed of three components: capital-related charges, net feedstock costs, and variable operation costs (Shapouri, Gallagher and Graboski, 1998). Figures Figure 24 and Figure 25 illustrate the cost trends of ethanol production from the last several years.

Feedstock – Corn Availability and Price

Corn availability in the county and surrounding area around the plant is essential for sustaining the plant's ethanol production. This requirement is fundamental for both location and capacity decisions. New producers need to make sure that sufficient corn is available around the plant to maintain maximum production and smooth operation. Furthermore, because corn procurement cost accounts for between 50% and 70% of ethanol production cost depending on purchasing price, paying a lower price for corn has a significant effect on producers' profits. The geographical region that is associated with abundance and low price of corn in the United States is called the Corn Belt¹². Figure 19 shows the Corn Belt region while figures Figure 10 and Figure 11 demonstrate planted corn and the price spatial distribution across the United States. Moreover, Figure 9 illustrates the dispersion of ethanol plants in the United States. By looking at these figures, the connection between lower corn price, corn availability, and ethanol plant locations becomes more obvious. The majority of the ethanol plants are located in the

¹² The Corn Belt region mainly includes the states of Iowa, Indiana, Illinois, and Ohio. Also, parts of South Dakota, North Dakota, Nebraska, Kansas, Minnesota, Wisconsin, Michigan, Missouri, and Kentucky.

Corn Belt or very close to this region where corn availability is high and price is low. An additional effect on the price plants pay for corn is the reduction in corn transportation costs (McNew and Griffith, 2005). For example, locating an ethanol plant next to corn producers in a low corn price region such as the Corn Belt benefits the plant twice. Not only are prices lower but producers saving on corn transportation costs.

Labor Cost and Diversity

The labor cost share according to Shapouri et al. (1998) is about 17% of dry mill ethanol production excluding feedstock cost. While striving to minimize labor cost, new plants prefer a larger and more skill-diverse local labor pool that increases the ability of a plant to recruit more productive workers at lower expense.

Electricity and Fuels

Although the energy cost of producing a gallon of ethanol has decreased by more than 50% in the last 15 years as technology has improved, the cost of electricity and fuel used to power an ethanol plant is still the largest component of the plant operation expenditure (and second overall after feedstock procurement¹³).

4.2.2 Plant Competition and Co-Products

Ethanol Plant Competition

Closeness between ethanol plants can increase the level of competition in the ethanol and corn markets. In order to maximize a plant's profit, the plant tries to reduce competition on inputs such as corn and therefore lower its price, while avoiding rivalry for selling ethanol and Dried Distiller's Grains (DDGs). As table 8 shows, in practice most of the U.S. counties contain one or no plants presumably in order to avoid competition.

¹³ See "Guide for Evaluating the Requirements of Ethanol Plants," The Clean Fuels Development Coalition, The Nebraska Ethanol Board and USDA, Summer 2006.

Co-Products

In the last few years most of the ethanol plants built in the industry have been dry mill. One reason is that capital and production investments for dry mill plants are significantly lower than for wet-mill plants. Today, dry mill plants comprise the majority of the total ethanol capacity in the nation. The co-products that result from dry mill ethanol production are Dried Distiller's Grains (DDGs) and CO₂. For every bushel (56 pounds) of corn used in the process, about 2.7 gallons of ethanol, 17 pounds of DDGs and 17 pounds of carbon dioxide are produced. Distillers Grain can be fed to livestock wet or dry but dry Distillers Grain has a longer shelf life. The other corn ingredients that are not used to produce ethanol are sold back to feedlots in the form of Distillers Grain. Selling DDGs provides a considerable share (for details see Figure 23) of the ethanol plant's revenue and helps reduce feedstock cost. In order to achieve maximum profit by selling DDGs, the plant should be located close enough to feedlots to minimize DDGs transportation costs and spoilage. In addition, the capacity of the new plant should be in line with the amount of DDGS that can be sold on a local market; otherwise the higher cost of transportation to DDGS consumers will reduce the revenue contribution it creates. In order to be able to benefit from this extra income DDGS offers, there is a necessity for DDGS storage. Farm product warehousing is important to enable marketing of DDGS and therefore is expected to be an additional determinant.

Carbon dioxide is used to carbonate beverages, manufacture dry ice, and to flash freeze meat. CO₂ is also used by paper mills and other food processors. Because selling CO₂ has significantly less effect on a plant's revenue than selling DDGS, some plants decide to evaporate it into the atmosphere rather than selling it.

4.2.3 Infrastructure

In order to operate efficiently and reliably, a new ethanol plant must carefully choose a location site that has adequate infrastructure.

Energy and Water

Proximity to energy sources such as natural gas pipelines and coal play an important role in the sustainability of the plant's operation. In some instances, proximity to power generating facilities can reduce the energy cost of the ethanol plant as well. When deciding on a plant's capacity it is necessary to ensure that enough energy will be available for a reasonable cost. Water quality, quantity, and infrastructure to handle treated water¹⁴ are also important considerations when deciding on a plant's location and capacity.

Transportation Network

Transportation cost is important in determining the marketing costs of ethanol. Consequently, a plant site that is efficiently networked with different transportation alternatives and many transportation providers is more likely to offer lower transportation costs. Ethanol is mainly shipped by truck, train, and barge. Truck shipments are more economical for short distances while barge and rail shipment are cheaper for long distance. The cost of shipping is based on access to different modes of transportation as well as shipment volume. As a result, plant proximity to major highways, railways, and rivers play a significant role when making location decisions. Furthermore, this requirement is more critical for plants with higher capacity as the shipment size increases and becomes more frequent.

4.2.4 Federal and State Level Regulation and Ethanol Tax Incentives

MTBE Ban

According to the U.S. Environmental Protection Agency (EPA), MTBE has been used in U.S. gasoline at low levels since 1979 to replace lead as an octane enhancer. A growing

¹⁴ See "Guide for Evaluating the Requirements of Ethanol Plants," The Clean Fuels Development Coalition, The Nebraska Ethanol Board and USDA, Summer 2006.

number of studies have found MTBE in drinking water throughout the country. Consequently, there is a growing concern over the need of MTBE as an oxygenate chemical. Ethanol usage as a replacement for MTBE is increasing over time as more states ban MTBE. Gasoline producers who used to formulate their products using MTBE are now forced to use other alternatives, the most common of which is ethanol.

Federal Incentives

Incentives for ethanol production are available at both the federal and state levels. Two major incentives at the federal level are the Volumetric Ethanol Excise Tax Credit (VEETC) and the Small Ethanol Producer Tax Credit. Other incentives such as infrastructure and labor training grants are available too. As opposed to the Small Ethanol Producer Tax Credit, the excise tax credit VEETC is an incentive for fuel blenders. VEETC provides blenders with an economic incentive to blend ethanol with gasoline. On January 1, 2009, the original tax credit totaling 51 cents per gallon on pure ethanol (5.1 cents per gallon for E10, and 42 cents per gallon on E85) was reduced to 45 cents per gallon¹⁵. Small ethanol producers are manufacturers who produce less than 60 million gallons of ethanol per year. They qualify for a tax credit equaling 10 cents per gallon on 15 million gallons of fuel ethanol. The maximum incentive is \$1.5 million annually.

State Incentives

The major incentives at the state level are an excise tax credit and producer tax credit. Different states offer different credit amounts while some do not offer incentives at all. The excise tax credit is in terms of per gallon tax exemption while the producer tax credit reduces the tax liability of the plant.

¹⁵ Source: American Coalition for Ethanol.

4.2.5 Other Determinants

Per Capita Income (PCI)

Areas with higher PCI are more likely to attract new investment as the population has greater purchasing power (Coughlin et al, 1991).

Agricultural regions

Different regions in the United States have different agricultural characteristics such as soil quality, average temperature, precipitation and the likelihood of adverse weather. As a result, many other factors that are unobserved may affect the location and capacity decisions of the plant and therefore have to be controlled using agricultural region dummies. For more details, see Figure 22.

4.3 Empirical Models

Both location and capacity decision models are presented below and use almost the same determinants as explanatory variables. Although the right hand sides of both models are similar, the two models use different econometric approaches and dependent variables. The location decision model is based on a Multinomial Logit model where the dependent variable is the county location of where the market entry occurred. The capacity decision is based on a Random Effects Tobit model where the dependent variable is the capacity size of the market entrant.

The reason for choosing Multinomial Logit for modeling the location decision is the realism that this econometric model offers. In practice, ethanol producers face multiple choices of where to locate their plants. Consequently, instead of using a Probit or a Logit model, where the location decision is represented by a binary variable (zero or one), a model that accounts for all entry possibilities simultaneously, such as the Multinomial Logit model, appropriately represents what happens in reality. The reason for choosing a Random Effects Tobit for modeling the capacity decision is the construction of the dependent variable, capacity of the new entrant. Because the variable capacity cannot take negative values, it is censored from the left at zero.

Both models described above are applied to a panel dataset for most U.S. counties and range between the years 2002 and 2008. The dataset used is discussed in detail in section 4.4.

4.3.1 The Multinomial Logit Model for the Location Decision

The multinomial logit model is used to model an ethanol plant's location decision. The probability for plant i to locate in county j in year t is specified to be:

$$P(Y_{it} = j | X_t) = \frac{\exp(X'_{jt}\beta)}{\sum_{k=1}^J \exp(X'_{kt}\beta)},$$

where X_t denotes the vector of explanatory variables listed in Table 9 for all of the counties in year t . As a result, the log likelihood for observation (plant) i is

$$LL_i(\beta) = \sum_{j=1}^J 1(Y_{it} = j) \log \left[\frac{\exp(X'_{jt}\beta)}{\sum_{k=1}^J \exp(X'_{kt}\beta)} \right],$$

where $1(Y_{it} = j)$ is the indicator function. The model is estimated using maximum likelihood.

4.3.2 The Random Effects Tobit Model for the Capacity Decision

The Random Effects Tobit model is used to model the capacity decision of the ethanol plants. In more detail, the capacity of a new plant i in county j in year t is specified to be:

$$Y_{ijt} = \begin{cases} X'_{jt}\beta + c_j + \varepsilon_{ijt} & \text{if } X'_{jt}\beta + c_j + \varepsilon_{ijt} > 0 \\ 0, & \text{otherwise} \end{cases},$$

where c_j is the random effects term. This captures all the time invariant and county specific factors other than those included in the covariate vector that are likely to influence the capacity decisions of new plants. Further, assuming that both the random effects term and the error term are normally distributed with zero means and variances σ_c^2 and σ_ε^2 respectively, the likelihood function for observation i is:

$$L_i = \int_{-\infty}^{+\infty} \phi\left(\frac{Y_{ijt} - X'_{jt}\beta - c_j}{\sigma_\varepsilon}\right)^{1(Y_{ijt}>0)} \Phi\left(\frac{-X'_{jt}\beta - c_j}{\sigma_\varepsilon}\right)^{1(Y_{ijt}=0)} \phi\left(\frac{c_j}{\sigma_c}\right) dc_j,$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ denote the pdf and cdf of the standard normal distribution, respectively. Since the likelihood function involves an integral, the simulated maximum likelihood estimation (SMLE) method is used to estimate the model.

4.4 Data

Data on ethanol plants for the years 2002 through 2008 are taken from the RFA (Renewable Fuel Association - <http://www.ethanolrfa.org/>). The dataset is built on seven annual reports (every February) for the years 2002 through 2008 and includes information on ethanol plants that are in operation and plants that are under construction during the years of analysis. The variables available from this dataset are plant name, feedstock used in production (this paper uses data only on plants that use corn as the feedstock), and nameplate capacity (the maximum production level the plant is permitted to produce). Several ethanol firms had multiple plants in the dataset and only one aggregate name plate capacity for all of them. Therefore, capacities for individual plants had to be recovered by contacting the firms or by using their internet web sites. Location information for U.S. ethanol plants is available from the RFA and Ethanol Producer Magazine (<http://www.ethanolproducer.com/>). Latitude and Longitude coordinates of the plants had to be collected separately by a third party using the plants' addresses.

Data for U.S. corn production and cattle numbers at the county level for the 48 continental states between the years 2002 and 2008 were collected from the USDA. All data are accessible through the National Agricultural Statistics Service web site (<http://www.nass.usda.gov/>). Additionally, information on different U.S. agriculture regions was taken from the USDA Economic Research Service (ERS). Coordinates for U.S. counties were taken from GIS software (Global Information System).

Data on corn prices were made available by Cash Grain Bids, which is a private consulting company for grain price intelligence. The price provided is an average price for every February for the years of analysis. Demographic data such as average wage, employment by sectors, and per capita income were collected by the U.S Bureau of Economic Analysis (<http://www.bea.gov/>). Data on employment for utilities, trucking, and farm product warehousing were collected from the County Business Pattern files from U.S. Census using the North American Industrial Classification System (NAICS) codes: 22 for Utilities, 484 for trucking and 493130 for farm product warehousing. Data on states banning the use of MTBE as well as ethanol incentives such as producer tax credits and excise tax exemption were taken from the Renewable Fuel Association (RFA) <http://www.ethanolrfa.org/> and the U.S. Environmental Protection Agency (EPA) (<http://www.epa.gov/>). The data on state level incentives and the MTBE ban were available only for the years 1999 and 2005 for incentives, and 2004 for MTBE ban. In order to have a panel dataset, it was necessary to extrapolate from this limited dataset. In the incentives dataset, most of the states (more than 60%) had incentives prior to the year 2002 (1999) and a sunset date later than the year 2008 (some have not yet had a sunset), so there was no reason to extrapolate for these states. However, there were some states that had no incentives in 1999 but did in 2005. In these cases, I used information online on the states' websites to complete this information. Unfortunately, I was not able to recover all of the incentives dates, so for these cases I used year 2005 as the incentive starting date. The data for MTBE ban was used as of year 2004. Data on major U.S. highways, rivers and railroads were taken from GIS software (Global Information System). The variables U.S. highways, railroads and rivers are available only for a single year but are included in the panel as they are not assumed to change significantly between the years 2002 and 2008.

When creating the final panel dataset and merging all variables together, there were counties with incomplete information. Because I am interested in a balanced dataset, I deleted all the counties (rows) in the final dataset that included missing values. The

number of counties in the dataset after deleting all counties with incomplete information is 2,836 per year. Since the dataset includes seven years between 2002 and 2008, I have a total number of 19,852 observations (2,836 x 7). The number of new plant entries and new plant capacities between the years of analysis was 90. Note, capacity expansions of existing ethanol plants are not considered as either new entry or new capacity. Table 10 report the summary statistics for the variables used in estimation.

This chapter employs the Great Circles method to calculate distances between two coordinates. Calculating the shortest distance between two points on a sphere (a good approximation for distance on the globe), can be done by using the following formula:

$$= ER * ACOS\{COS[RADIANS(90 - Lat_1)] * COS[RADIANS(90 - Lat_2)] + SIN[RADIANS(90 - Lat_1)] * SIN[RADIANS(90 - Lat_2)] * COS[RADIANS(Long_1 - Long_2)]\}$$

Where ER is the earth radius measured in miles. Lat₁ and Lat₂ are the latitudes of the two points of interest. Long₁ and Long₂ are the longitudes of the two points of interest.

Note: In this formula, Lat₁, Lat₂, Long₁, and Long₂ must be entered as decimal degrees (e.g. 45.5 rather than 45:30:00).

4.5 Results

The results from both location and capacity decision models of new ethanol plants indicate that the most statistically significant determinants are Corn Availability in the county and the surrounding areas, existence of previous ethanol plants (PrPlant) in the county, and the number of Cattle within the county. Tables 11 and 12 show the

estimation results of the Multinomial Logit model and the Random Effects Tobit model as well as the marginal effects of all variables in the capacity model¹⁶. As expected, corn availability, which is essential to the plant operation, is indeed found to positively affect location and capacity decisions. The estimated coefficients for this variable are positive and highly significant. The more corn available in a county and its surrounding areas, the more likely an ethanol producer is to enter the county and build a larger capacity plant. Corn accounts for the largest share in the cost of ethanol production. In a county with a lot of corn, the new plants not only place themselves in a region with an abundance of corn, but also save crucial transportation costs by locating the plant closer to corn producers (McNew and Griffith, 2005). Using the marginal effect results for the variable CornAva from the capacity model indicates that for every additional one billion bushels of effective corn (for more details, see CornAva definition in table 9) around the ethanol plant, producers tend to increase the capacity of the plant by almost 3.1 million gallons annually.

The existence of a previous ethanol plant in a county is found to reduce the likelihood of plant entry and large-capacity plant construction. The coefficient for this variable is found to be negative and significant at the 5% level. The logic behind this result is that new entrants are likely to avoid direct competition for their final product and input markets by taking their business to plant-free counties. Using the marginal effect results for the PrPlant variable from the capacity model shows that the presence of an existing plant within the county reduces the capacity of the new plant by 2.1 million gallons annually. This estimate is considered small as it accounts only for only 2.1% from a typical 100 annual million gallons.

The number of cattle within the county is also found to be positive and highly significant. The market for Dried Distillers Grain (DDGs), which is a co-product of

¹⁶ Note, the marginal effects for the location model could not be calculated because of the estimation complexity and the lack of econometric software that can work with a high number of choices (a Multinomial Logit panel model with 2836 choices).

ethanol production and can be used as feed for cattle, has considerable influence on location and capacity decisions of new ethanol plants. By being close to a large market for DDGS, a new ethanol plant is able to reduce co-products' transportation costs and to increase its revenue. Additionally, having a larger market for DDGS supports ethanol plants with a higher level of capacity that produce greater amounts of DDGS. The large local DDGS market ensures short transportation distances. The marginal effect results from the capacity model suggest that an increase in cattle population of 100,000 head within the county will encourage ethanol producers to increase the new plant capacity by 14.2 million gallons annually. It is important to note that ideally, the cattle variable should have been constructed the same way as the CornAva variable. That is to say, the variable should represent not only the cattle within the county but also cattle in the surrounding counties by aggregating cattle and weight their impact on ethanol capacity by distance. In this chapter I use cattle within the county because aggregating and weighting cattle around each county requires the development of a separate model for the cattle industry which is beyond of the scope of this chapter. This additional model is essential for producing the cattle distance discount factor estimate that provides the weights for cattle in different locations.

The coefficient for the Herfindahl Index (HHI) is negative as expected; however it has a p-value of 0.1 in the capacity model and 0.13 in the location model. This variable measures work force diversity in each county by summing the squared shares of employment of each industry from the total workforce. For more details, see table 9. Although this variable is not highly significant, it indicates that workforce diversity is somewhat important for new ethanol producers as they have to hire diverse, skilled labor to operate the plant. The marginal effect for this variable in the capacity model implies about 15 annual million gallons larger capacity for a diverse labor pool (with HHI close to zero) versus no or low diversity (with HHI close to one).

Contrary to expectations, the coefficient on the River Adjacency (RiverAdj) variable is negative and significant at the 10% significance level (p-value close to 0.09 in both location and capacity models). One would think that proximity to rivers would increase the likelihood of locating a new ethanol plant because of the ability to transport grain on barges. This surprising result might be caused by how this variable is defined. The one-mile cutoff point might be too small. It can be the case that locating the plant too close to a river may have negative impacts on the plant.

Northern Great Plains and Prairie Gateway agricultural region dummies, Reg3 and Reg4, represent the area to the north-west and south-west of the Corn Belt region and include states both within the belt and outside of it. The estimated coefficients for these two dummies are significant and positive at 5% and 1% levels respectively in both location and capacity models, implying that ethanol plants are more likely to be located in this region compared to the Heartland region (base region – Reg1). This indicates an ethanol industry expansion from the center of the Corn Belt outside toward the west. The marginal effect results of both regions in the capacity model indicate a capacity increase of about 2.5 million gallons annually for plants that were to be located in these regions as oppose to other locations. For more details see the map in Figure 22.

The coefficients for the variable MTBE ban (MTBE) are positive but not statistically significant in both models. The p-values are 0.21 in the capacity model and 0.17 in the location model. Similarly, the tax incentive variables, Producer Tax Credit (ProducerCredit) and Excise Tax Credit (TaxCredit), are insignificant for both location and capacity models as well. While Producer Tax Credit has the expected sign (positive), the Excise Tax Credit has a negative sign. It is hard to believe that MTBE as well as ethanol incentives are not important to location and capacity decisions of ethanol plants. The reason for such insignificant results might be due to the fact that the panel dataset used here is incomplete. As mentioned in the data section, the data on the variables MTBE and tax incentives (Producer Tax Credit and Excise Tax Credit) are

incomplete and in order to conduct a panel data analysis, there was a need to extrapolate the data. Consequently, it is important to collect a more complete panel dataset and repeat the analysis to be certain of the results. Although having incomplete panel data for the variable MTBE, I can still perform a simulation analysis that will examine the effect of MTBE ban on ethanol plant locations and capacities. For more information, see section 5.2 (Counterfactual Simulation Results).

I find the Corn Price (CornPrice) variable to have a negative sign in both location and capacity models as expected. Ethanol plant producers strive to minimize the cost of ethanol production by locating their plants where corn price is low. Figures Figure 10 Figure 11 show the relationship between corn abundance and lower corn price counties. Using these two figures one can see that lower corn price regions seem to be where there is abundance of corn (in the Corn Belt). Figure 9 demonstrates that ethanol producers do choose to locate their plants in corn abundance and low corn price regions. Although the coefficient on the Corn Price variable has the expected sign, it is insignificant in both models.

The two variables measuring the efficiency of the transportation network for inputs and outputs, Road Density (RoadDensity) and Rail Density (RailDensity), have a positive coefficient in the location model as I expected. Counties with denser transportation networks have greater shipping reliability as well as more transportation flexibility and alternatives. These two variables are insignificant, however. In the capacity model, only the coefficient on the Road Density variable has a positive sign while the coefficient on the Rail Density variable has a negative sign. The coefficients for the location quotients for Trucking (LQ484) and Farm Product Warehousing (LQ493130) are positive as I expected in both location and capacity models but insignificant. Counties that specialize in trucking and farm product warehousing have higher probabilities of attracting new ethanol plants. On the contrary, the coefficients for the location quotient for utilities (LQ22) variables are found to be insignificant and negative in both models.

The Wage (Wage) and per capita income (PCI) variables have opposite signs to the expectations in both location and capacity models; however both are insignificant in both models. The Wage variable has a positive effect while PCI has a negative effect. Wage represents one component of the ethanol production cost. The explanation for a positive coefficient sign on the Wage variable may be due to the lack of accounting for workers' quality. Ethanol plants require workers with special skills or training and therefore, these higher skilled or trained workers tend to cost more.

4.5.1 Counterfactual Simulation Results

Next, I use the estimation results to conduct counterfactual policy experiments. The ethanol industry is an emerging industry and has expanded significantly over the past decade. Policy makers might be interested in knowing the effects of certain government policies on the evolution of this new industry. For example, they may want to know if the MTBE had never been banned, how the ethanol plants would have been distributed across the nation nowadays. As an illustration, below I show how to use the results obtained in this paper to answer this question. To do so, I conducted a simulation experiment. The simulation starts with the recalculation of the probabilities of plant location entrance for each county in the year 2002, using the estimates and the observed covariates and setting the MTBE ban variable equal to zero for all counties. Then, I rank all counties by their probabilities and chose the N counties with the highest probabilities as the places where new plants where have entered. N is the number of plants that entered the ethanol market in 2002 in the dataset. After doing this for 2002, I update the variable PrPlant (existence of previous plant) for 2003 in the dataset according to the simulation plant entrance that took place in 2002. After the update, I repeat what I did for the year 2002 to predict where plants would enter in 2003. The same procedure is then iterated until 2008.

The results from this simulation are collected in table 13. The table compares the results from the simulation (MTBE=0 for all counties) and the predicted values using the original MTBE vector from the dataset at the state level. The variable PrPlant was updated identically in both specifications. The difference between the two indicates that had MTBE not banned, plant dispersion would have been a little different. Taking out the MTBE ban, Minnesota and Iowa would each lose one plant entry whereas Texas would gain two new plant entries. Minnesota and Iowa, which had MTBE bans in the original dataset, lose this competitive advantage when I set the MTBE vector to be zero for all the counties. On the other hand, Texas that does not ban MTBE in the original dataset attracts these two plants. Consequently, MTBE ban is not found to be a major determinant affecting ethanol plant location decision, although it has a positive effect. Using the estimates from the Random Effects Tobit model, I also predict what the capacities for the new ethanol plants would be had the MTBE never been banned. Since capacity is a positive number, I calculated the predicted capacity conditional on the capacity being positive using the following formula:

$$E(Y_{ijt} | Y_{ijt} > 0, X_{jt}) = X_{jt}' \hat{\beta} + \hat{\sigma}_{\varepsilon} \int_{-\infty}^{+\infty} \frac{\phi\left(\frac{X_{jt}' \hat{\beta} + c_j}{\hat{\sigma}_{\varepsilon}}\right)}{\Phi\left(\frac{X_{jt}' \hat{\beta} + c_j}{\hat{\sigma}_{\varepsilon}}\right)} \phi\left(\frac{c_j}{\hat{\sigma}_c}\right) dc_j.$$

The results reveal a reduction in plant capacity of 7.5% on average had MTBE not been banned.

In conclusion, as result of these two simulations of ethanol plant location and capacity MTBE ban might not affect plant location decision significantly however once this decision is made, the MTBE ban supports larger plant capacities.

4.6 Conclusion

This study models location and capacity decisions for new ethanol plants using data on various determinants including corn availability and price, numbers of cattle, competition of other ethanol plants, producers' incentives, the MTBE bans, and transportation network. The study uses Multinomial Logit and Random Effects models to analyze location and capacity decisions respectively. Additionally, the study employs two simulations for ethanol plants' locations and capacities in order to predict plants' capacities and distribution in the case where MTBE had not been banned.

The major determinants found affecting ethanol plant location and capacity decisions are corn availability, the existence of a plant prior to the new entry, and the number of local cattle. The simulation result from the ethanol plant location model shows that if MTBE had not been banned, ethanol plant dispersion across the United States would have been slightly different. Minnesota and Iowa would each lose one plant entry while Texas would gain two new plant entries. Furthermore the result from the ethanol plant capacity model indicates that capacity would have been 7.5% lower on average for all new plant entries.

In order to take the next step of this study, future research can integrate plant location and capacity models into a single and more complex model that jointly accounts for both decisions. In reality, the two decisions may affect each other or one can be more important to the firm than the other. A different idea would be to use predicted estimates for the explanatory variables for both location and capacity models and by using the location and capacity simulations, predict future ethanol plants' dispersion across the United States and their capacities. In addition, further data collection is desirable especially for MTBE and producer incentives. Moreover, data on energy prices at a county or a state level and incorporating then into the model is likely to be important.

Because energy is the second-largest cost in ethanol production, it is likely to be a significant determinant for location and capacity decisions.

The RFS mandate required a production of 10.5 billion gallons of corn-based ethanol in 2009 and 15 billion gallons by 2015. As of 2010, according to the RFA, estimated U.S. ethanol production was 10.6 billion gallons. It is unclear what will be the number of ethanol producers once the RFS mandate reaches the 15 billion gallons level and stays there (until the year 2022, as mandated). Because the major ethanol industry expansion has occurred only in the last decade, this industry has not been much researched and therefore has plenty of room for further investigation. The following research questions are good examples. At what point in time will plant entry cease in the corn-based ethanol industry? Is it going to happen before 2015 or later? Will the ethanol price drop significantly in the future as more producers enter the market? Will the corn market keep up its production to meet the needs of the corn-based ethanol industry growth? Will only the most efficient ethanol plants survive?

Tables

Table 1. U.S. Corn Supply and Demand 2002-2008
(million acres/bushels, USDA)

	2002- 2003	2003- 2004	2004- 2005	2005- 2006	2006- 2007	2007- 2008
Planted Area (M Acres)	78.9	78.6	80.9	81.8	78.3	93.5
Harvested Area (M Acres)	69.3	70.9	73.6	75.1	70.6	86.58
Yield (Bu/Acre)	129.3	142.2	160.3	147.9	149.1	150.7
Beginning Stock (M Bu)	1,596	1,087	958	2,114	1,967	1,304
Production	8,967	10,087	11,806	11,112	10,531	13,038
Imports	14	14	11	9	12	20
Supply, Total	10,578	11,188	12,775	13,235	12,510	14,362
Feed and Residual	5,563	5,793	6,155	6,152	5,591	5,938
Food, seed and Industry	2,340	2,537	2,687	2,982	3,490	4,363
Ethanol for Fuel	996	1,168	1,323	1,603	2,119	3,026
Domestic Total	7,903	8,330	8,843	9,134	9,081	10,302
Total Exports	1,588	1,900	1,818	2,134	2,125	2,436
Use, Total	9,491	10,230	10,661	11,268	11,207	12,737
Ending Stocks	1,087	958	2,114	1,967	1,304	1,624
Stocks/Use Ratio	11.4%	9.4%	19.8%	17.5%	11.6%	12.8%

Table 2. Non-Linear Least Squares (NLS) Results for 286.17-mile radius

Variable	Estimate	Standard Error	t-Stat
Capacity	5.214322	0.683386	7.630128
Lagged Corn	-0.01156	0.008912	-1.29686
Lagged Soybeans	0.237282	0.009707	24.44493
D3	-200.954	146.1527	-1.37496
D4	961.7047	146.0798	6.583418
D5	40.60264	148.0236	0.274298
D6	-1471.67	147.6481	-9.96741
D7	6097.809	153.1195	39.82385
D8	-4447.42	172.3125	-25.8102

Table 3. Confidence Interval Comparison - NLS, residual bootstrap, and block bootstrap

Variable	NLS CI	Residual Bootstrap CI	Block Bootstrap CI (20-Mile Neighbors)
Radius	N/A	209.83 , 389.10	249.99 , 517.61
Capacity	4.09 , 6.34	3.03 , 7.76	2.4461 , 10.4220
Lagged Corn	-0.0262 , 0.0031	-0.0267 , 0.003	-0.0311 , 0.1709
Lagged Soybeans	0.221 , 0.253	0.2208 , 0.2535	0.1729 , 0.2769

Table 4. Comparison between NLS and Spatial Error Estimates

Variable	NLS	t-Stat NLS	Spatial Error Model (Contiguity)	t-Stat Spatial Error Model (Contiguity)	Spatial Error Model (Inverse Distance)	t-Stat Spatial Error Model (Inverse Distance)
Capacity	5.2143	7.630128	3.9682	3.5881	3.9582	4.4371
Lagged Corn	-0.01156	-1.29686	0.016517	2.4341	0.015926	1.7896
Lagged Soybeans	0.2372	24.44493	0.20863	18.642	0.20883	21.218

Table 5. Block Bootstrap Estimator Confidence Intervals Using Different Neighbors' Distances

Distance Definition of Neighbors (Miles)	CI Radius		CI Capacity		CI Lagged Corn		CI Lagged Soybeans	
20	249.99	517.61	2.4461	10.4220	-0.0311	0.1709	0.1729	0.2769
50	130.86	517.75	-4.7456	9.1235	-0.0326	0.2492	0.1504	0.2986
100	132.46	537.58	-7.6956	10.4319	-0.0760	0.2976	0.1177	0.3099
200	131.53	534.22	-8.4422	10.8812	-0.1312	0.3310	0.0822	0.3177
500	148.02	523.77	-5.1570	9.1459	-0.0981	0.3752	0.1497	0.3203
800	164.10	365.46	-5.1784	6.3939	-0.0846	0.3495	0.1525	0.3113
1000	168.19	336.31	-5.5307	5.5938	-0.0975	0.3104	0.1664	0.2967
1500	276.11	286.90	4.5178	5.2665	-0.0809	0.0536	0.2347	0.2578
2000	279.40	286.88	4.8615	5.2143	-0.0135	0.0345	0.2373	0.2468
2500	286.16	286.16	5.2143	5.2143	-0.0116	-0.0116	0.2373	0.2373
2600	286.16	286.16	5.2143	5.2143	-0.0116	-0.0116	0.2373	0.2373

Table 5. Radius Confidence Interval Values
(Graphical Representation) **Based on Neighbors Distance Definition**

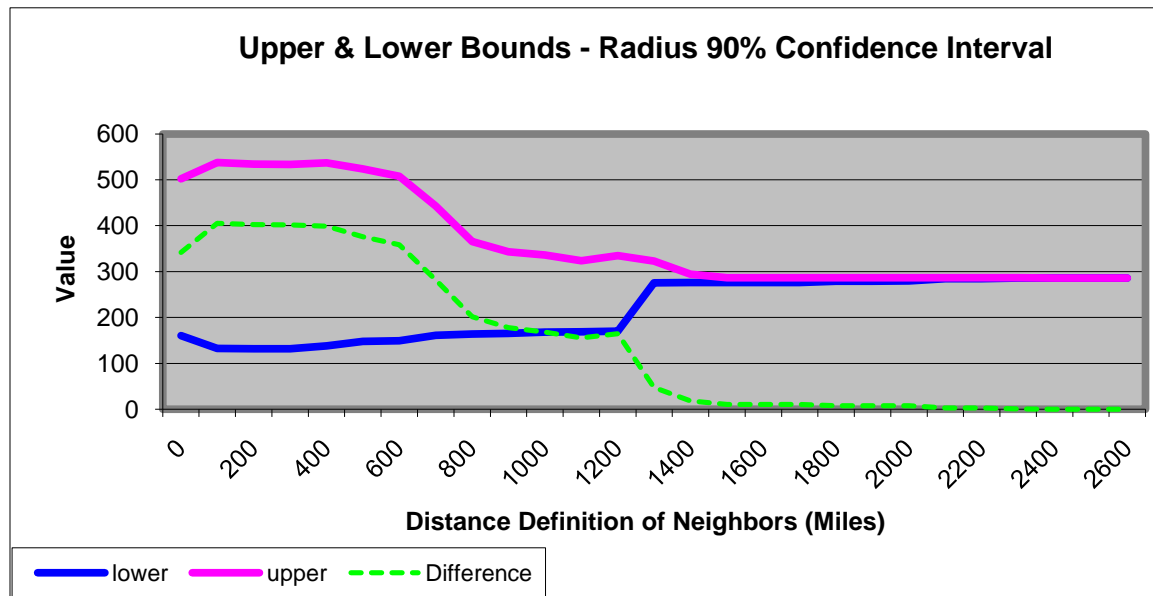


Table 6. Econometric Results - Restricted and Non-Restricted Models

Model	ZED Radius	Estimate (β)	S.E	t-stat
Restricted Slopes	103.19	0.0193	0.0015	12.7322
Non-Restricted Slopes	upstream 101.47	0.01893	0.00148	12.73648
	downstream 107.57			

Note: ZED = Zero Effective Distance (in miles).
Number of Observations = 2,975 (both models).
Restricted Slopes $R^2 = 0.82$, Non-Restricted Slopes $R^2 = 0.8724$.

Table 7. Summary Statistics - Aggregated Basis Effect of Ethanol Plants' Capacities on Corn Markets 2002-2008 (cents per bushel)

Year	Minimum	Maximum	Mean
2002	0.00	0.86	0.04
2003	0.00	1.88	0.37
2004	0.00	3.25	0.53
2005	0.00	4.13	0.95
2006	0.00	6.36	1.65
2007	0.00	10.63	2.71
2008	0.00	13.09	3.90

Note: Statistics are calculated based on 425 corn markets. Zero basis effect from ethanol plants pertain to markets which the distance between them and the nearest ethanol plants is more than 103 miles.

Table 8. Frequency distribution of ethanol plants by county 2002-2008

# of Plants/Year	2008	2007	2006	2005	2004	2003	2002
0	2990	3019	3033	3045	3056	3060	3067
1	116	88	75	64	53	50	43
2	6	5	4	3	3	2	2
Total Counties	3,112	3,112	3,112	3,112	3,112	3,112	3,112

Table 9. Multinomial Logit Model (MNL) and Random Effects Tobit Model (RET) – Explanatory Variables and Definitions

Variable	Symbol	Definition	Note	Expected Sign
New Entry _{it} (Dependent Variable)	NewEntry	New ethanol plant location entry in county i and year t. Plant has started production for the first time (yes=1, no=0).	Appears only in MNL	
New Capacity _{it} (Dependent Variable)	NewCap	The capacity of a new ethanol plant, i, which starts production for the first time in year t, measured in annual million gallons.	Appears only in RET	
Corn Availability _{it}	CornAva	Total corn available in county i and the surrounding areas for year t, measured in bushels. The variable is calculated by aggregating corn production weighted by distance from county i in the surrounding area using a 286-mile radius ¹⁷ .		+
Plant Competition _{it}	PrPlant	Indicates whether an ethanol plant already exists in county i and year t (yes=1, no=0).		-
Cattle _{it}	Cattle	number of cattle heads in county i and year t.		+
Corn Price _{it}	CornPrice	February average corn price in county i and year t, measured in cents.		-
MTBE Ban _{it}	MTBE	MTBE ban adoption in county i and year t, binary variable (yes=1, no=0).		+

¹⁷ The radius of 286 miles used is based on a study investigating the effect of ethanol plants on corn production. See Fatal, 2011a.

Table 9. Continued

Excise Tax Credit _{it}	TaxCredit	Ethanol producers excise tax credit in county i and year t, (yes=1, no=0).	+
Producer Tax Credit _{it}	ProducerCredit	Ethanol producer credit program in county i and year t, (yes=1, no=0).	+
Road Density _{it}	RoadDensity	Ratio of total highway miles to area in square miles in county i and year t.	+
Rail Density _{it}	RailDensity	Ratio of total railroads miles to area in square miles in county i and year t.	+
River Adjacency _{it}	RiverAdj	Adjacency to rivers of county i and year t (yes=1, no=0). Adjacency is defined as up to one-mile distance.	+
Wage _{it}	Wage	Annual average wage in county i and year t, measured in U.S dollars.	-
Per Capita Income _{it}	PCI	Per capita income in county i and year t, measured in U.S dollars.	+
Utilities Location Quotient _{it}	LQ22	Location Quotient ¹⁸ of utilities in county i and year t.	+
Trucking Location Quotient _{it}	LQ484	Location Quotient ¹⁸ of trucking in county i and year t.	+
Farm Product Location Quotient _{it}	LQ493130	Location Quotient ¹⁸ of farm product warehousing in county i and year t.	+

¹⁸ The purpose of the Location Quotient is to compare employment in a certain region with the national norm.

The formula is as follows: $\frac{e_i/e}{E_i/E}$ where e_i is local employment in industry i, e is total local employment, E_i is national employment in industry i and E is total national employment.

Table 9. Continued

Herfindahl index _{it}	HHI	Herfindahl index ¹⁹ in county i and year t, between zero and one.	-
Agricultural Region _i	Reg1 – Reg9	Binary agriculture region indicators of county i and year t. The nine regions are Heartland, Northern Crescent, Northern Great Plains, Prairie Gateway, Eastern Uplands, Southern Seaboard, Fruitful Rim, Basin and Range, and Mississippi Portal. The analysis uses the Heartland region (Reg1 which includes most of the Corn Belt) as a base for the rest of the regions.	
Time Dummies	Dum03- Dum08	Six year 2003-2008 dummies using year 2002 as the base year.	Appears only in RET

¹⁹ HHI sums the squared shares of employment of each industry i from the total workforce $\sum s_i$. HHI value closer to one means less workforce diversity and vice versa.

Table 10. U.S. Counties Descriptive Statistics 2002-2008

	MEAN	STD	MIN	MAX
CornAva (Million Bushels)	498.18	686.1	0	2,895
Cattle (Cattle Heads)	32,851	46,793	100	1,063,000
CornPrice (U.S. Cents)	295.6	110.5	140.6	567.6
Wage (U.S. Dollars)	28,880	6,134	15,136	85,335
PCI (U.S. Dollars)	27,045	6,652	451	142,739
LQ22	1.677	3.475	0	84.769
LQ484	1.405	1.711	0	46.495
LQ493130	3.763	23.443	0	856.734
HHI	0.047	0.030	7.78×10^{-7}	0.521
RoadDensity	0.400	0.260	0	2.883
RailDensity	0.092	0.084	0	0.787
RiverAdj (yes=1, no=0)	0.306		0	1
PrPlant (yes=1, no=0)	0.021		0	1
MTBE (yes=1, no=0)	0.426		0	1
TaxCredit (yes=1, no=0)	0.136		0	1
ProducerCredit (yes=1, no=0)	0.351		0	1
Reg2	0.111		0	1
Reg3	0.060		0	1
Reg4	0.134		0	1
Reg5	0.135		0	1
Reg6	0.154		0	1
Reg7	0.094		0	1
Reg8	0.066		0	1
Reg9	0.056		0	1
NewCapacity	0.237		0	130
NewEntry	0.005		0	1

Table 11. Multinomial Logit Results for Location Decision

Variable	Estimate	Standard Error	P-Value
CornAvailability	1.5259x10 ⁻⁹	2.803x10 ⁻¹⁰	<.0001
PrPlant	-1.1138	0.5322	0.0364
Cattle	6.3058x10 ⁻⁶	1.0502x10 ⁻⁶	<.0001
CornPrice	-0.003765	0.007677	0.6238
MTBE	0.5673	0.4141	0.1707
TaxCredit	0.1805	0.3143	0.5658
ProducerCredit	0.0412	0.2522	0.8704
RoadDensity	0.00217	0.4723	0.9963
RailDensity	0.1379	1.4823	0.9259
RiverAdj	-0.455	0.2685	0.0902
Wage	0.0000308	0.0000264	0.2431
PCI	-0.000019	0.000026	0.4543
LQ22	-0.0196	0.0445	0.6598
LQ484	0.0458	0.0497	0.3572
LQ493130	0.000334	0.005904	0.9549
HHI	-6.659	4.484	0.1375
Reg2	0.4913	0.431	0.2544
Reg3	1.2108	0.5498	0.0277
Reg4	1.2801	0.4359	0.0033
Reg5	-15.2144	1224	0.9901
Reg6	-14.6292	1189	0.9902
Reg7	0.3155	0.8715	0.7174
Reg8	0.2929	1.1492	0.7988
Reg9	-14.8066	1976	0.994

Note: Total number of observations is 19,852. The log likelihood result is -609.66.

Likelihood ratio statistic = 211.7.

Table 12. Random Effects Tobit Model Results for Capacity Decision

Variable	Estimate	Standard Error	P-Value	Marginal Effect
CornAvailability	7.8x10 ⁻⁸	1.57x10 ⁻⁸	<.0001	3.09x10 ⁻⁹
PrPlant	-57.19771	26.91616	0.034	-2.1036
Cattle	0.0003583	0.0000732	<.0001	0.0000142
CornPrice	-0.2503641	0.3744861	0.504	-0.00991
MTBE	23.09233	18.53939	0.213	0.919
TaxCredit	-11.18887	16.1221	0.488	-0.438
ProducerCredit	-0.6869877	12.54631	0.956	-0.02719
RoadDensity	3.57991	22.43518	0.873	0.1417
RailDensity	-4.824811	77.94749	0.951	-0.191
RiverAdj	-23.07507	13.52876	0.088	-0.9026
PCI	-0.0008269	0.0013075	0.527	-0.00003
Wage	0.0016194	0.0013684	0.237	0.00006
LQ22	-0.9536263	2.107746	0.651	-0.03776
LQ484	2.569268	2.807444	0.36	0.1017
LQ493130	0.0904477	0.2506726	0.718	0.0035
HHI	-378.2416	232.0502	0.103	-14.9774
Reg2	23.01894	21.49961	0.284	0.934
Reg3	64.73252	28.04664	0.021	2.784
Reg4	58.74868	22.60978	0.009	2.476
Reg5	-546.3729	612344	0.999	-14.417
Reg6	-512.9331	665875.2	0.999	-14.119
Reg7	15.01894	41.8416	0.72	-0.605
Reg8	26.5028	47.6087	0.578	1.084
Reg9	-522.4585	1090188	1.00	-12.646

Table 12. Continued

Dum03	30.85659	32.7948	0.347	1.26
Dum04	25.0731	42.4711	0.555	1.0184
Dum05	22.64279	27.03602	0.402	0.9173
Dum06	32.64342	27.17933	0.23	1.3363
Dum07	78.88561	80.20715	0.325	3.393
Dum08	151.4981	117.109	0.196	7.0939
Constant	-440.3406	96.69517	<.0001	

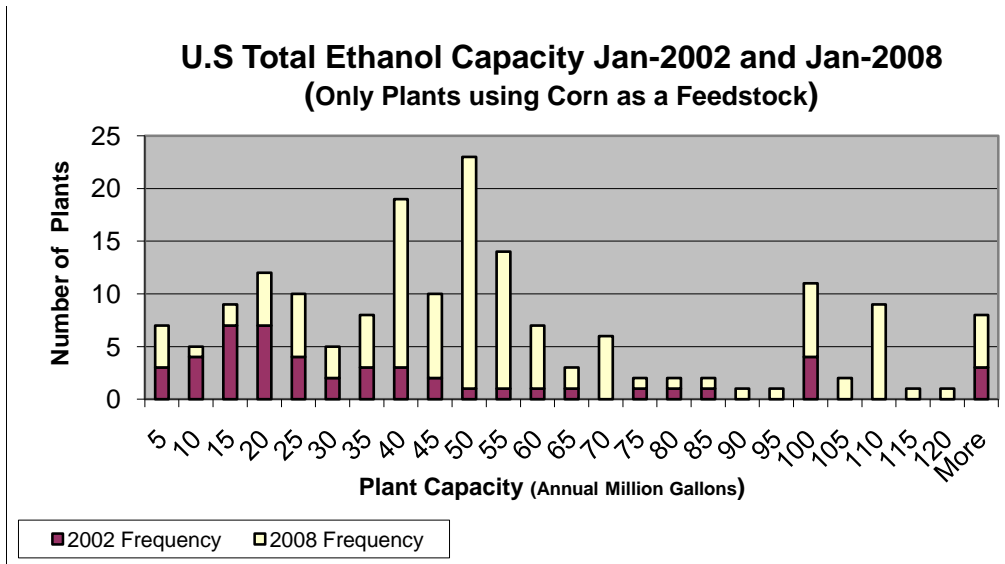
Note: Total number of observations is 19,852. The log likelihood is -890.08. Wald chi2 = 65
All marginal effects are insignificant at 10%.

Table 13. Plants' Location Simulation Results

State	Simulation		
	Simulation (MTBE=0)	(MTBE= Original Values)	Difference
CA	6	6	0
CO	5	5	0
IA	45	46	-1
IL	5	5	0
KS	2	2	0
MN	1	2	-1
NE	14	14	0
SD	3	3	0
TX	3	1	2
WI	6	6	0
Total Plants	90	90	

Note: States that are not shown in the table above have zero plant entries between the years 2002-2008.

Figures



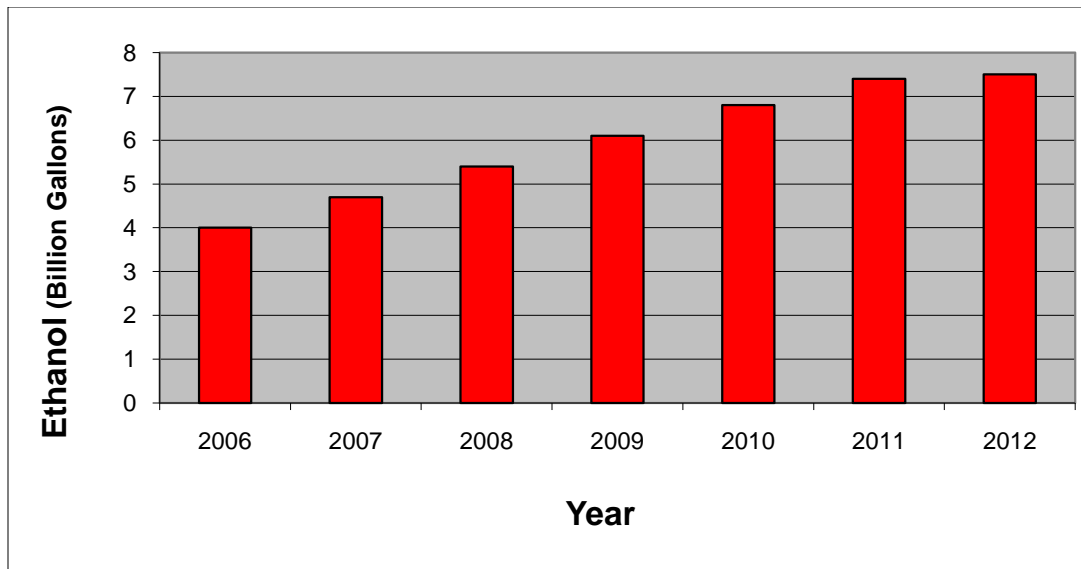
Source: Renewable Fuels Association (RFA)

Figure 5. U.S. Ethanol Plant Production Capacity 2002-2008

Figure 5 as a Table

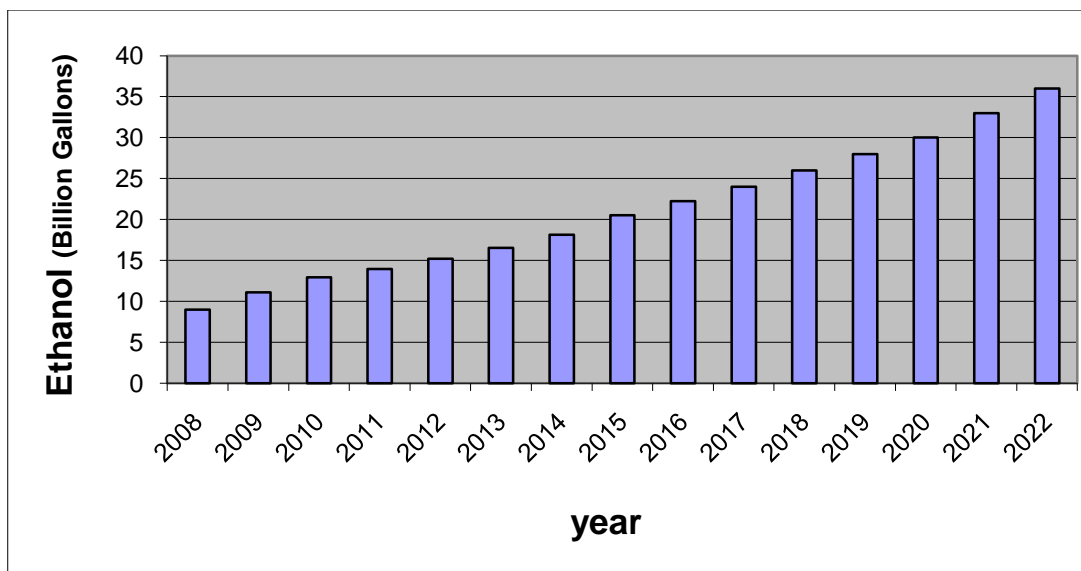
Year	2008	2007	2006	2005	2004	2003	2002
Total Capacity	7,826	5,340	4,275	3,608	3,006	2,615	2,390
Change in Total Capacity	2486.5	1064.5	667	602.5	391	224.5	N/A
% Change in Total Capacity	46.57%	24.90%	18.49%	20.05%	14.96%	9.39%	N/A
Plant Mean Capacity	60.67	54.48	50.89	50.82	50.94	48.42	48.78
Plant Median Capacity	50	45	43	40	40	35	22
Plant Min Capacity	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Plant Max Capacity	290	290	290	290	290	290	290
Plant 1Q Capacity	40	33.5	26.125	23.5	20.5	18	15
Plant 3Q Capacity	68	54.25	50	50	48	46.5	52
Plant Capacity Std	43.91	47.27	48.29	51.56	56.53	59.59	63.04
Number of Plants	129	98	84	71	59	54	49
Change in Number of Plants	31	14	13	12	5	5	N/A
% in the Number of Plants	31.63%	16.67%	18.31%	20.34%	9.26%	10.20%	N/A

* **Note** – The change in the number of plants is different than the number of new entries as plants also may exit the market. Also, numbers presented in the above table might be different from other sources as this table contains only corn-based ethanol plant capacities. 1Q is the first quartile (25th percentile).



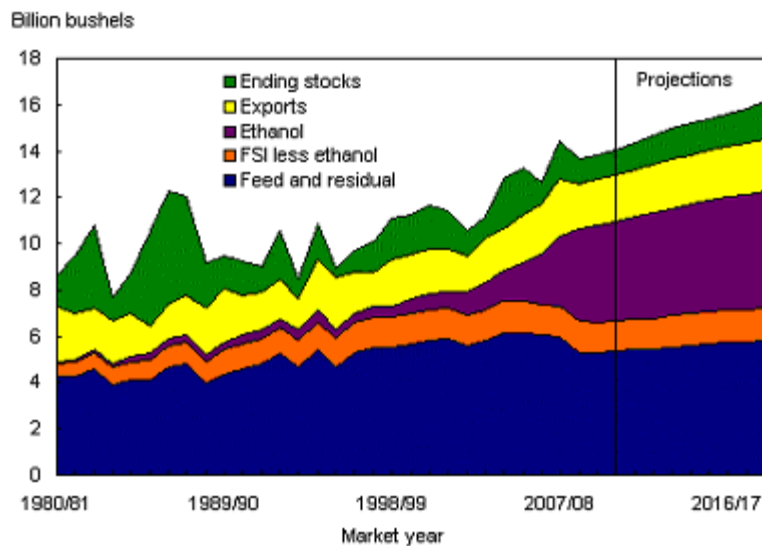
Source: Energy Policy Act of 2005

Figure 6. First Renewable Fuel Standard 2006-2012 (Energy Policy Act of 2005)



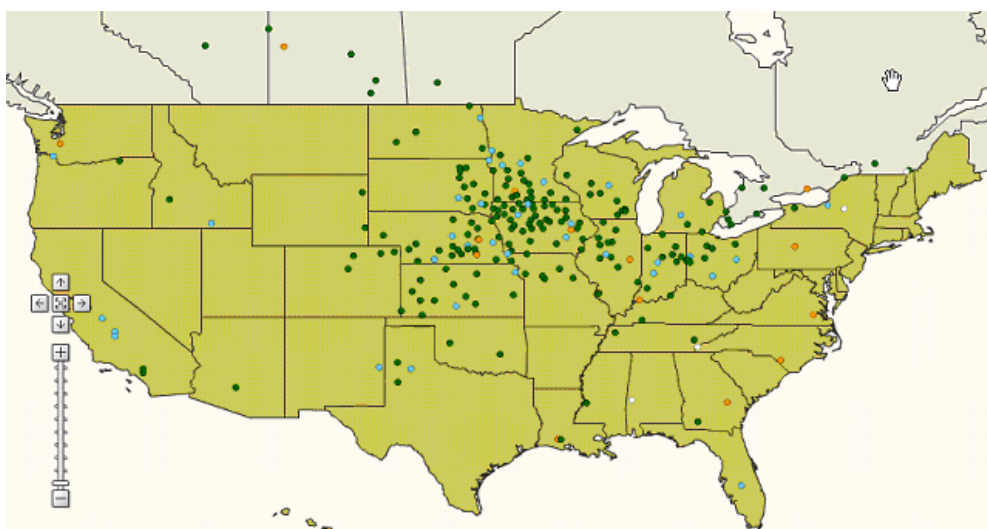
Source: Energy Independence and Security Act of 2007

Figure 7. Second Renewable Fuel Standard 2008-2022 (Energy Independence and Security Act of 2007)



Source: USDA Agricultural Projections to 2018, February 2009. USDA Economic Research Service.

Figure 8. U.S. Corn Utilization (USDA)

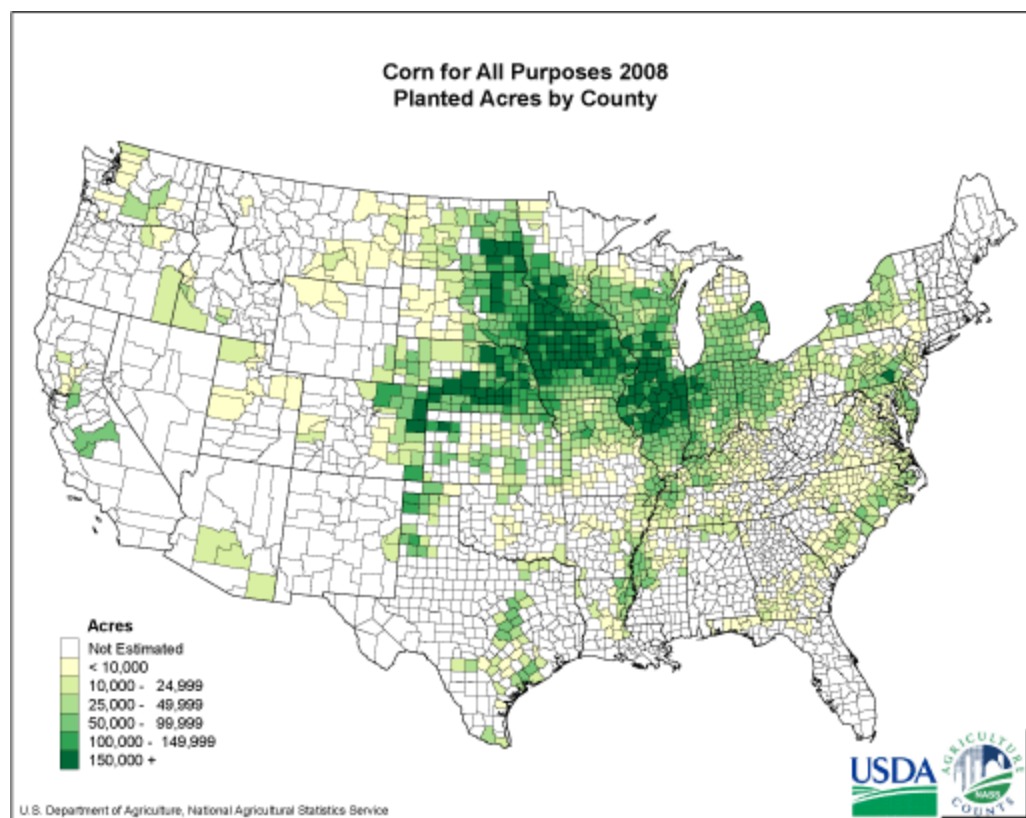


Map Key:

- Producing
- Idle
- Under Construction
- Unknown

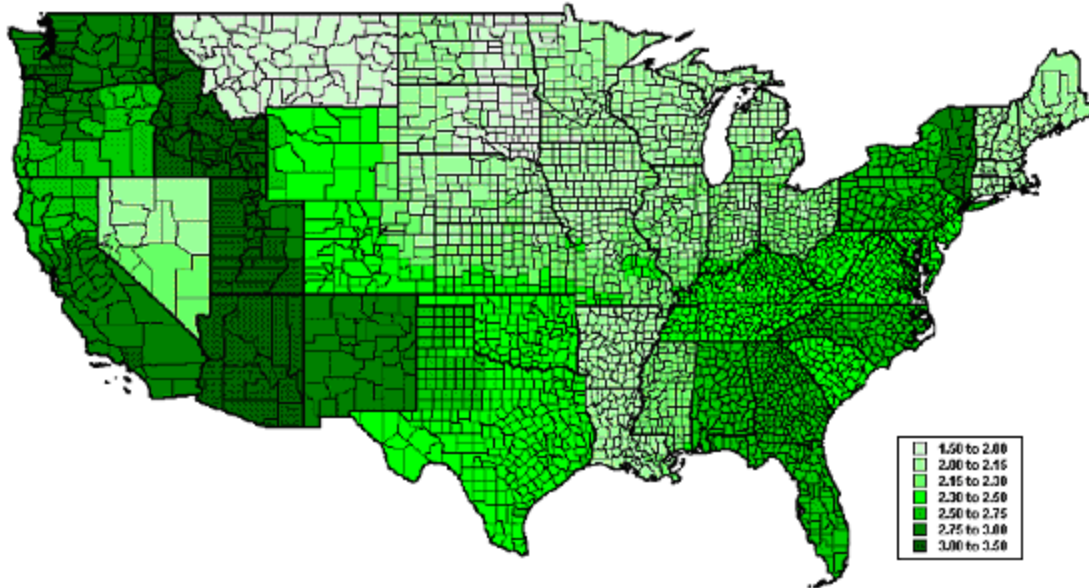
Source: Ethanol Producer Magazine, August 2009.

Figure 9. U.S. Ethanol Plant Map



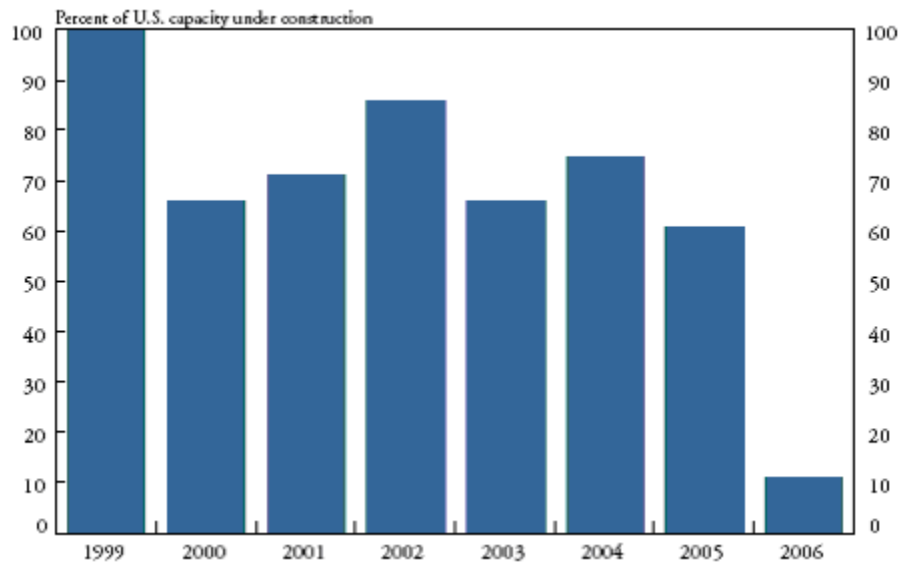
Source: USDA, 2008.

Figure 10. U.S. Planted Corn (2008 USDA Publication)



Source: USDA, 2002.

Figure 11. U.S. Spatial Corn Price



Source: Renewable Fuels Association (RFA)

Figure 12. Percentage of U.S. Ethanol Capacity under Construction Owned by Farmers

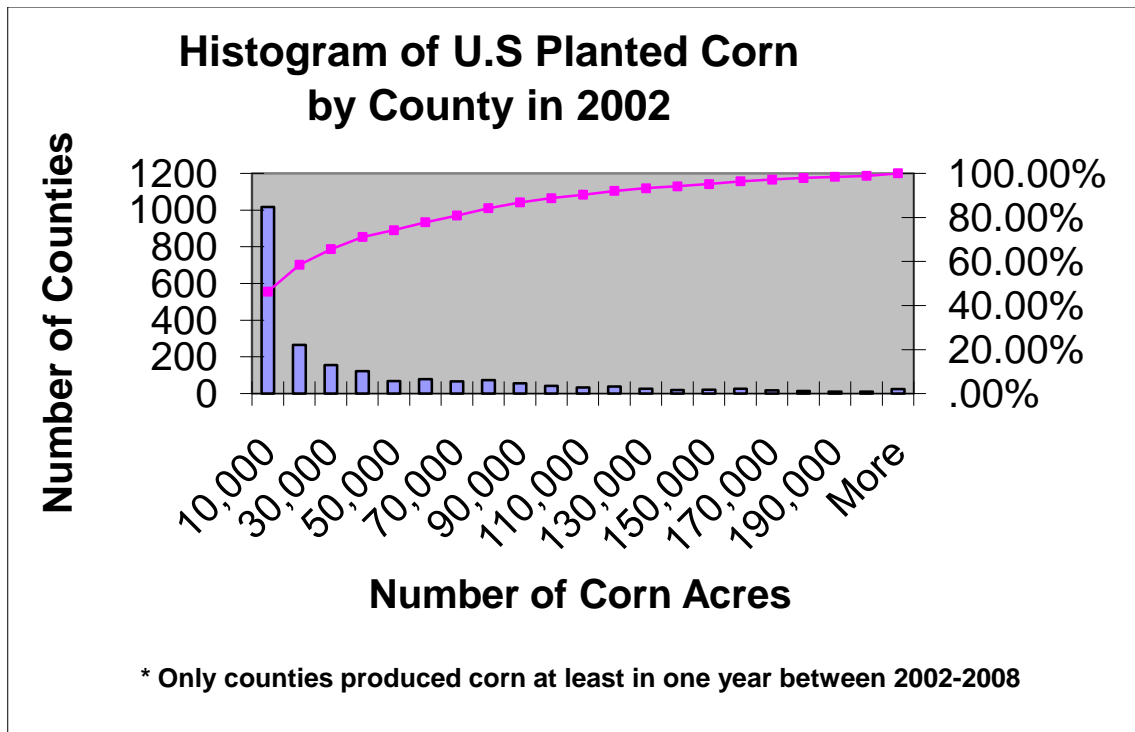


Figure 13. U.S. Planted Corn Histogram (2002)

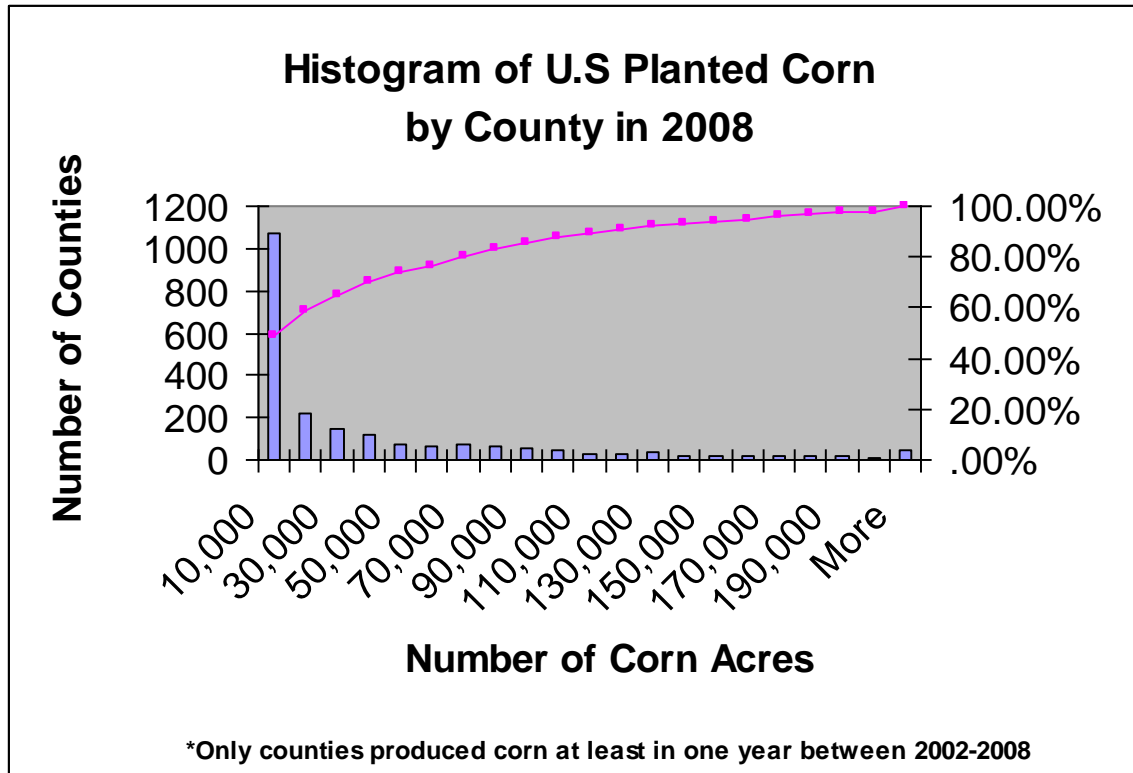


Figure 14. U.S. Planted Corn Histogram (2008)

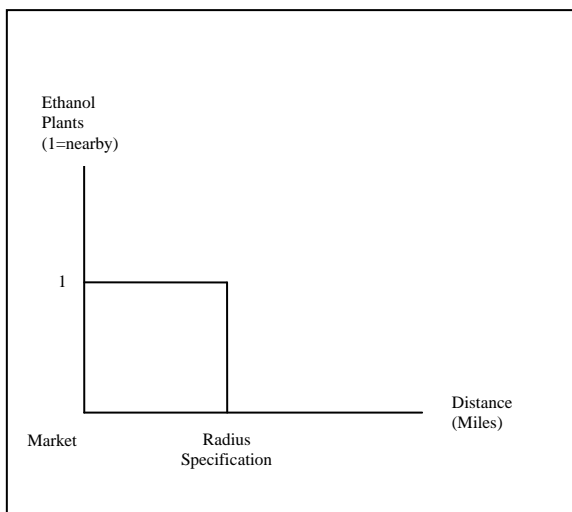


Figure 15. Nearby Ethanol Plants within Radius (1=within)

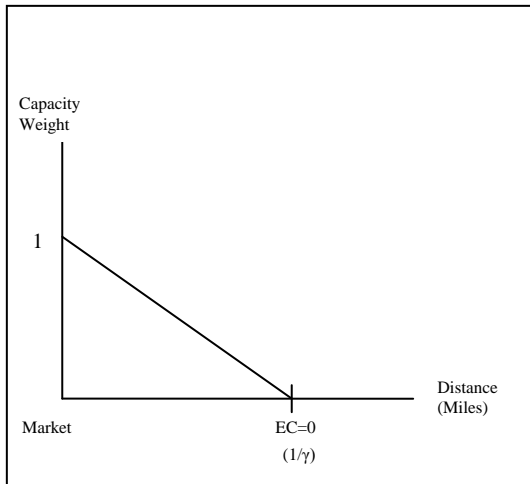


Figure 16. Ethanol Plants within Radius
(weight diminishes with distance, until $EC=0$)

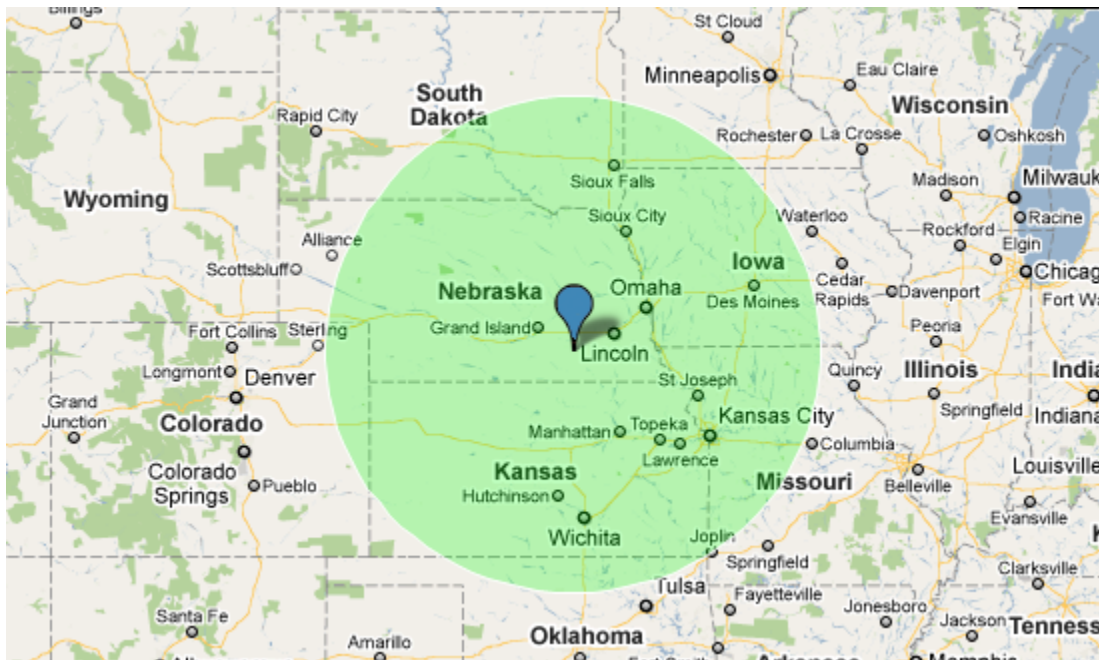


Figure 17. Radius of 286.17-Mile around Advanced Bioenergy,
Fillmore County NE

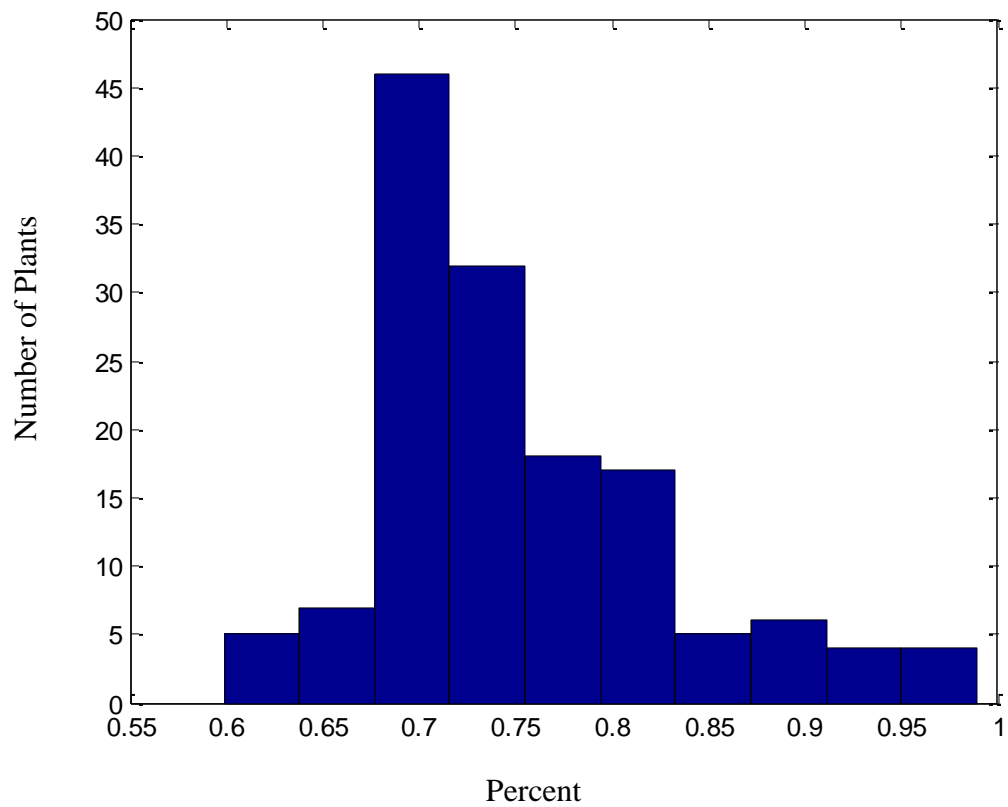
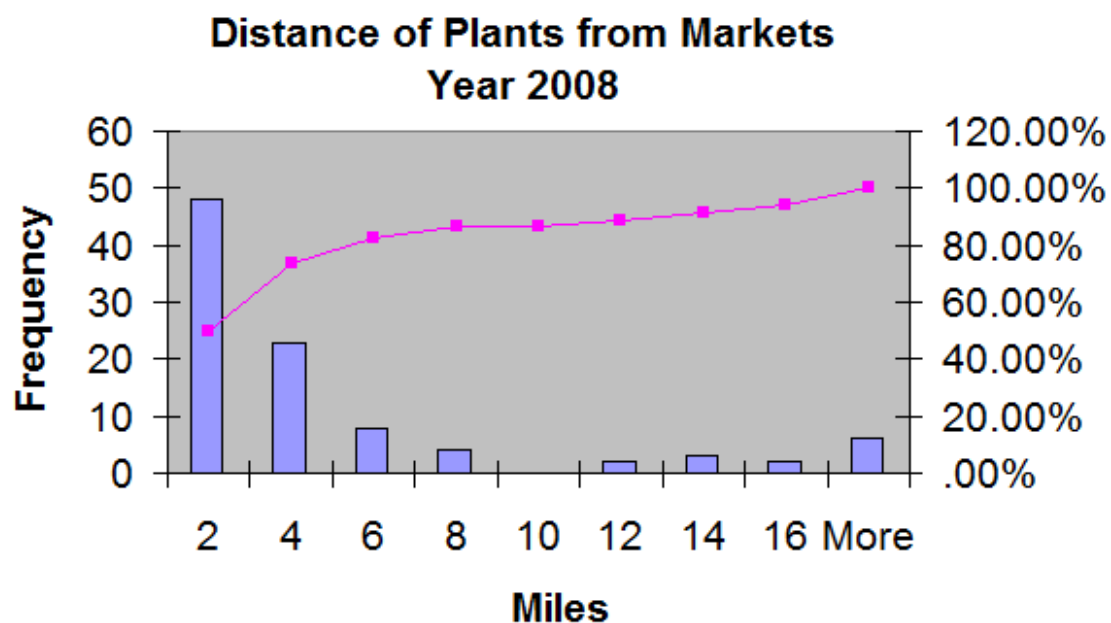


Figure 18. Plants' Corn Deficit Histogram



Source: Encyclopedia Britannica 2010.

Figure 19. U.S. Corn Belt Region



* The y axis on right indicates the cumulative frequency.

Figure 20. Distance Distribution of Ethanol Plants to Corn Markets (2008)

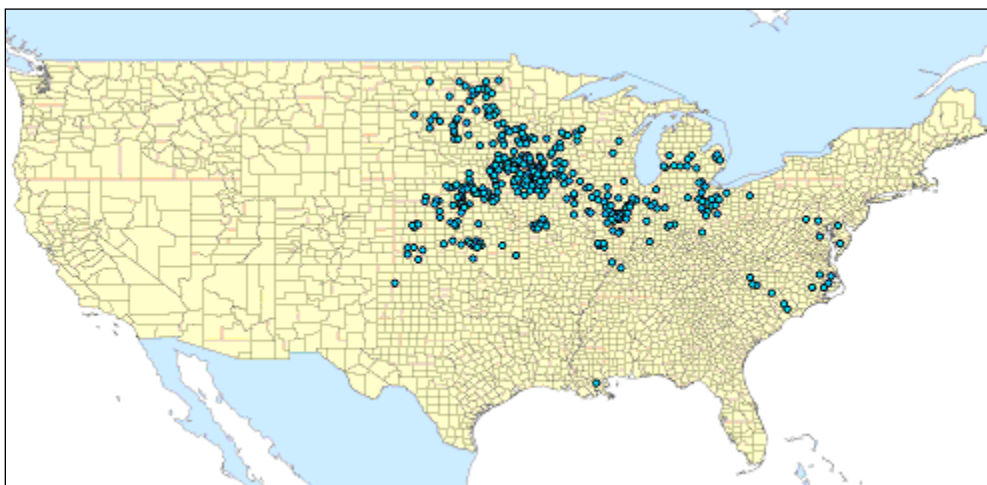
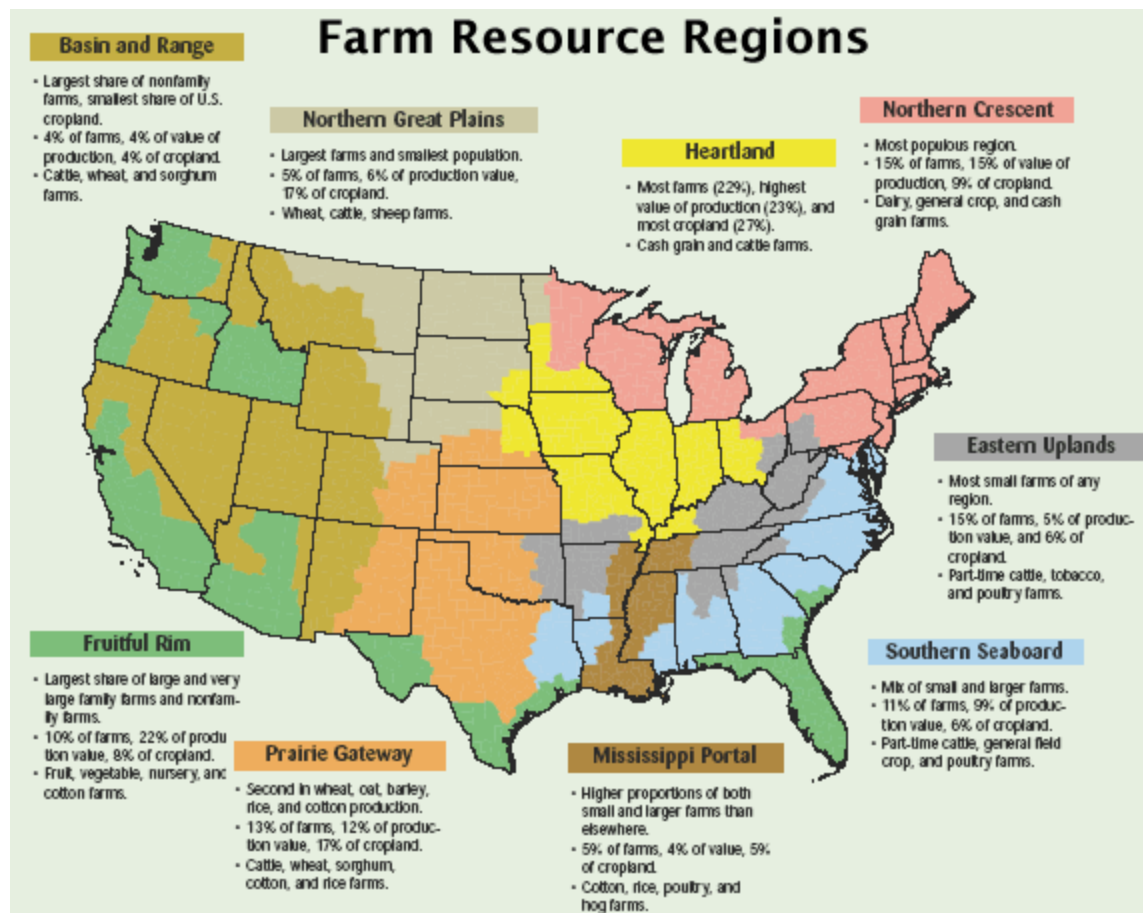
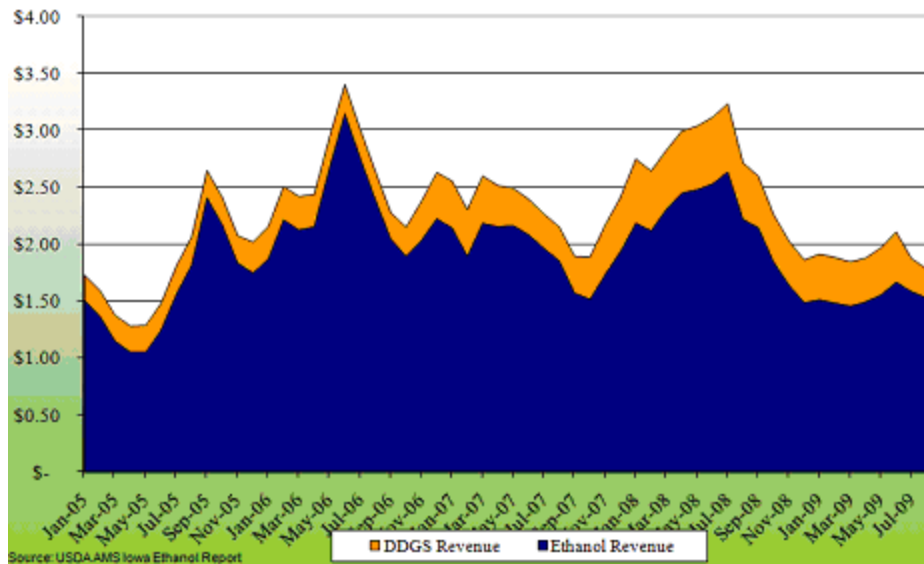


Figure 21. Corn Market Locations (425 markets)



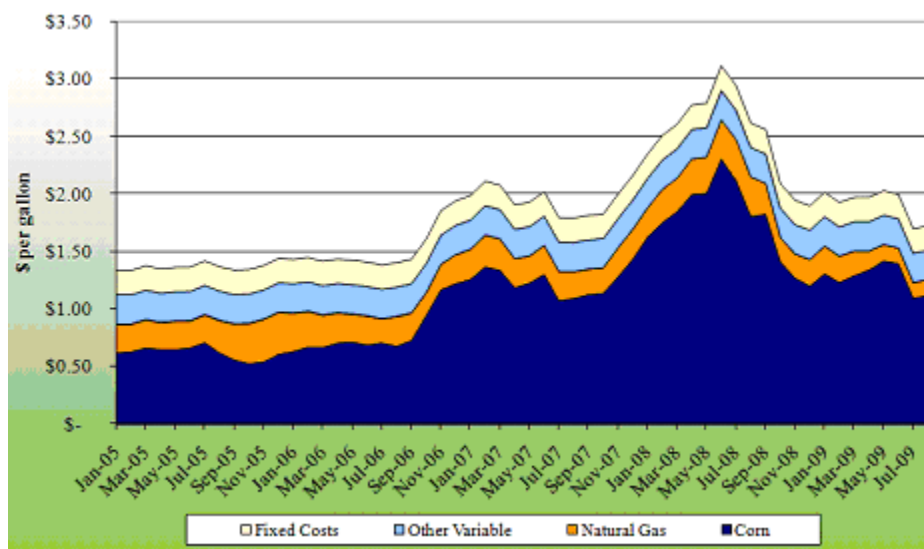
Source: USDA, 2008.

Figure 22. Agricultural Regions



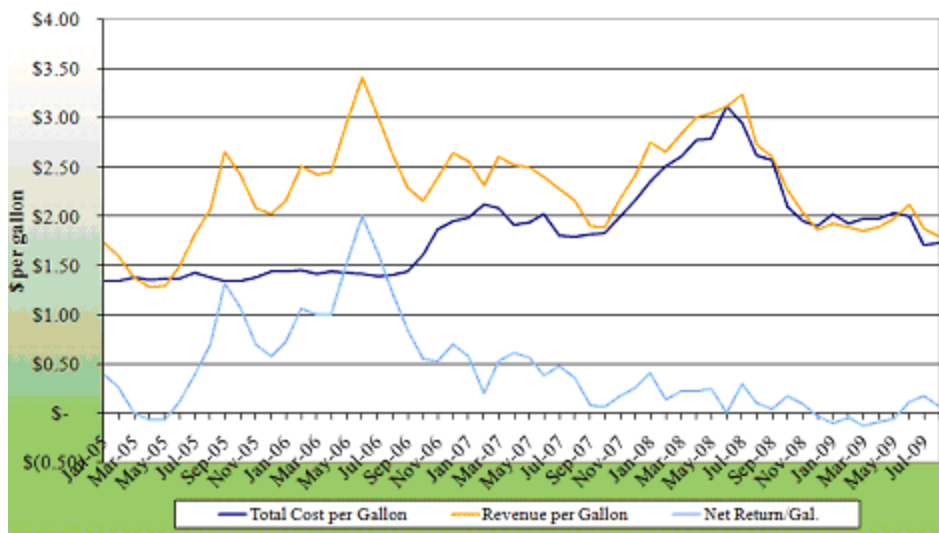
Source: USDA AMS Iowa Ethanol Report

Figure 23. Ethanol Producer's Total Revenue per Gallon 2005-2009 (ethanol, DDGS, and total)



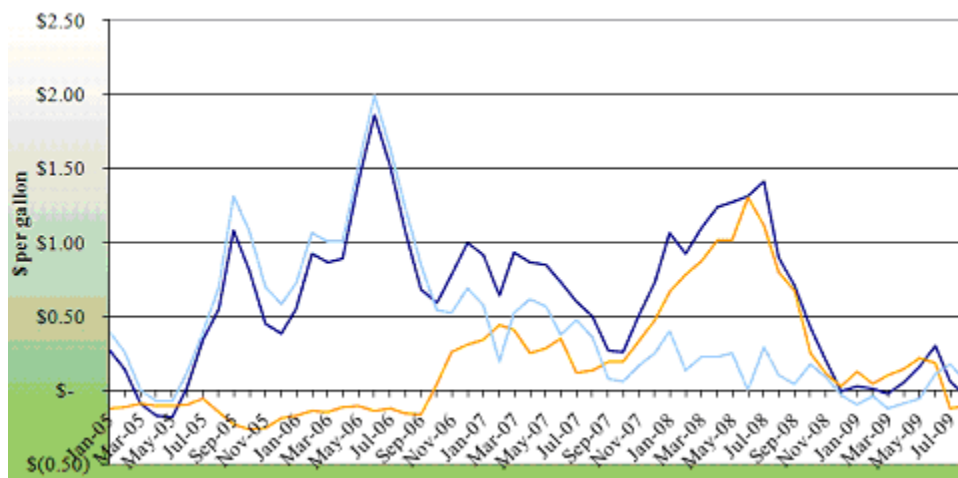
Source: USDA AMS Iowa Ethanol Report, EIA.

Figure 24. Cost of Ethanol Production 2005-2009 (\$/gallon, corn at market price)



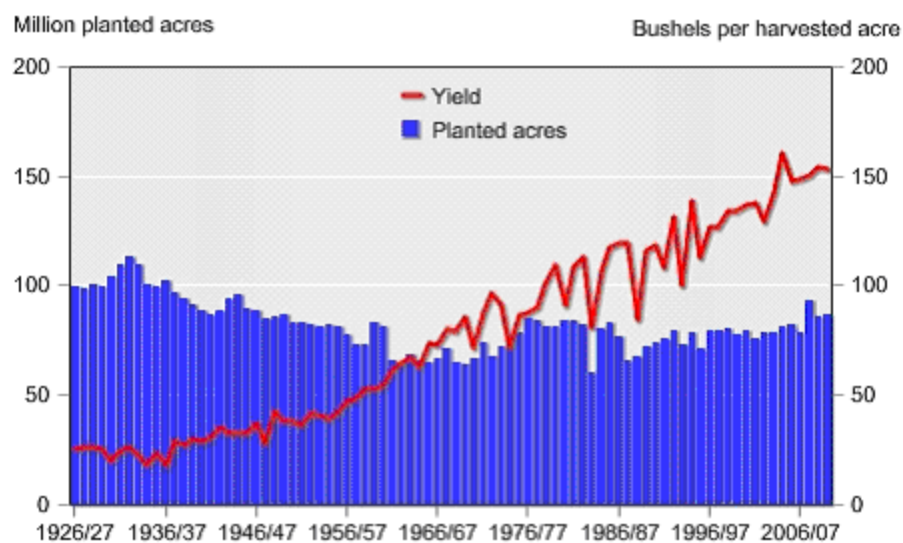
Source: USDA AMS Iowa Ethanol Report, EIA.

Figure 25. Ethanol Producer's Revenue, Cost, and Profit 2005-2009 (\$/gallon, corn at market price)



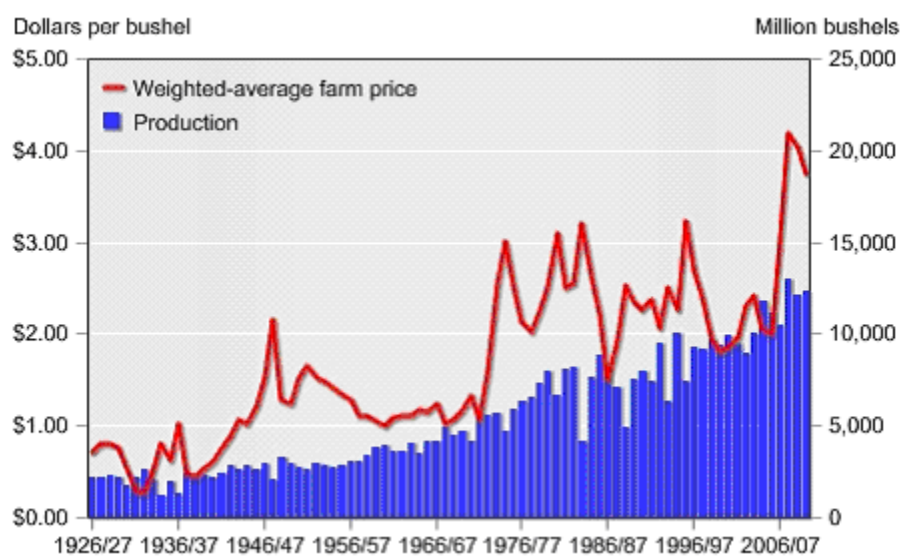
Source: USDA AMS Iowa Ethanol Report

Figure 26. Profit of Ethanol Producers and Corn Farmers 2005-2009 (\$ per gallon, corn at production cost)



Source: USDA World Agricultural Outlook Board,
World Agricultural Supply and Demand Estimates. Updated July 2009.

Figure 27. U.S. Corn Planted Acreage and yield



Source: USDA World Agricultural Outlook Board,
World Agricultural Supply and Demand Estimates. Updated July 2009.

Figure 28. U.S. Corn Price Received by Farms and Production

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Appendices

Appendix 1. List of U.S. Ethanol Plants Used in the Dissertation

(All plants use corn as feedstock for ethanol production)

The following ethanol plant list represents information such as location and feedstock used in production of those plants used in the analysis. Some of the plants are used in only a few of the years while others are used throughout the analysis (2002-2008). The reason for that evolves from the fact some plants started production later than 2002, or exited the market during the years of analysis.

Plant #	Plant Name	City	State	County	FIPS	Feedstock
1	A.E. Staley	Loudon	TN	Loudon	47105	Corn
2	Abengoa Bioenergy Corp. (year 2003 or before - the name was High Plains Corp.)	Colwich	KS	Sedgwick	20173	Milo / Corn
3	Abengoa Bioenergy Corp.(year 2003 or before - the name was High Plains Corp.)	Ravenna	NE	Buffalo	31019	Corn
4	Abengoa Bioenergy Corp.(year 2003 or before - the name was High Plains Corp.)	York	NE	York	31185	Corn
5	Ace Ethanol LLC	Stanley	WI	Chippewa	55017	Corn
6	Adkins Energy LLC	Lena	IL	Stephenson	17177	Corn
7	Advanced Bioenergy	Fairmont	NE	Fillmore	31059	Corn
8	AGP	Hastings	NE	Adams	31001	Corn
9	Agra Resources Coop (EXOL)	Albert Lea	MN	Freeborn	27047	Corn
10	Agri-Energy LLC	Luverne	MN	Rock	27133	Corn
11	Alchem Ltd. LLLP	Grafton	ND	Walsh	38099	Corn
12	Al-Corn Clean Fuel	Claremont	MN	Dodge	27039	Corn
13	Amaizing Energy LLC	Denison	IA	Crawford	19047	Corn
14	Archer Daniels Midland Co.	Decatur	IL	Macon	17115	Corn
15	Archer Daniels Midland Co.	Peoria	IL	Peoria	17143	Corn
16	Archer Daniels Midland Co.	Clinton	IA	Clinton	19045	Corn
17	Archer Daniels Midland Co.	Cedar Rapids	IA	Linn	19113	Corn
18	Archer Daniels Midland Co.	Marshall	MN	Lyon	27083	Corn
19	Archer Daniels Midland Co.	Columbus	NE	Platte	31141	Corn
20	Archer Daniels Midland Co.	Walhalla	ND	Pembina	38067	Corn
21	Arkalon Energy, LLC	Liberal	KS	Seward	20175	Corn
22	Aventine Renewable Energy Inc. (year 2003 or before - the name was Williams Bio-Energy)	Aurora	Ne	Hamilton	31081	Corn
23	Aventine Renewable Energy Inc.(year 2003 or before - the name was Williams Bio-Energy)	Pekin	IL	Tazewell	17179	Corn

Appendix 1. Continued

24	Badger State Ethanol LLC	Monroe West	WI	Green	55045	Corn
25	Big River Resources LLC	Burlington	IA	Des Moines	19057	Corn
26	Blue Flint Ethanol	Underwood	ND	McLean	38055	Corn
27	Bonanza Energy, LLC	Garden City	KS	Finney	20055	Corn/Milo
28	Broin Enterprises, Inc.	Scotland	SD	Bon Homm	46009	Corn
29	Bushmills Ethanol LLC	Atwater	MN	Kandiyohi	27067	Corn
30	Cargill Inc.	Eddyville	IA	Wapello	19179	Corn
31	Cargill Inc.	Blair	NE	Washington	31177	Corn
32	Central Indiana Ethanol, LLC	Marion	IN	Shelby	18145	Corn
33	Central Minnesota Ethanol Co-op	Little Falls	MN	Morrison	27097	Corn
34	Chief Ethanol Fuels Inc.	Hastings	NE	Adams	31001	Corn
35	Chippewa Valley Ethanol Co. LLLP	Benson	MN	Swift	27151	Corn
36	Commonwealth Agri-Energy LLC	Hopkinsville	KY	Christian	21047	Corn
37	Corn LP	Goldfield	IA	Wright	19197	Corn
38	Corn Plus LLLP	Winnebago	MN	Faribault	27043	Corn
39	Cornhusker Energy Lexington LLC	Lexington	NE	Dawson	31047	corn
40	Dakota Ethanol LLC	Wentworth	SD	Lake	46079	Corn
41	DENCO LLC	Morris	MN	Stevens	27149	Corn
42	E Energy Adams, LLC	Adams	NE	Gage	31067	Corn
43	East Kansas Agri-Energy LLC	Garnett	KS	Anderson	20003	Corn
44	Elkhorn Valley Ethanol, LLC	Norfolk	NE	Madison	31119	Corn
45	ESE Alcohol	Leoti	KS	Wichita	20203	Seed Corn
46	Ethanol2000, LLP (Poet)	Bingham Lake	MN	Cottonwood	27033	Corn
47	Front Range Energy LLC	Windsor	CO	Larimer	8069	Corn
48	Frontier Ethanol, LLC (Poet)	Gowrie	IA	Webster	19187	Corn
49	Gateway Ethanol	Pratt	KS	Pratt	20151	Corn
50	Glacial Lakes Energy LLC	Watertown	SD	Codington	46029	Corn
51	Global Ethanol, LLC	Lakota	IA	Kossuth	19109	Corn
52	Global Ethanol, LLC	Riga	MI	Lenawee Cerro	26091	Corn
53	Golden Grain Energy LLC	Mason City	IA	Gordo	19033	Corn
54	Golden Triangle Energy Co-op Inc.	Craig	MO	Holt	29087	Corn
55	Gopher State Ethanol	St. Paul	MN	Ramsey	27123	Corn
56	Grain Processing Corp.	Muscatine	IA	Muscatine Yellow	19139	Corn
57	Granite Falls Energy LLC	Granite Falls	MN	Medicine	27173	Corn
58	Great Plains Ethanol LLC (Poet)	Chancellor	SD	Turner	46125	Corn
59	Green Plains Renewable Energy	Shenandoah	IA	Page	19145	Corn
60	Hawkeye Renewables	Fairbank	IA	Buchanan	19019	Corn
61	Hawkeye Renewables	Iowa Falls	IA	Hardin	19083	Corn
62	Heartland Corn Products	Winthrop	MN	Sibley	27143	Corn
63	Heartland Grain Fuels LP	Huron	SD	Beadle	46005	Corn

Appendix 1. Continued

64	Heartland Grain Fuels LP	Aberdeen	SD	Brown	46013	Corn
65	Horizon Ethanol, LLC (Poet)	Jewell	IA	Hamilton	19079	Corn
66	Husker Ag LLC	Plainview	NE	Pierce	31139	Corn
67	Illinois River Energy, LLC	Rochelle	IL	Ogle	17141	Corn
68	Iowa Ethanol, LLC (Poet)	Hanlontown	IA	Worth	19195	Corn
69	Iroquois Bio-Energy Company, LLC	Rensselaer	IN	Jasper	18073	Corn
70	James Valley Ethanol, LLC (Poet)	Groton	SD	Brown	46013	Corn
71	KAAPA Ethanol LLC	Minden/Axtell	NE	Kearney	31099	Corn
72	Lifeline Foods, LLC	St. Joseph	MO	Buchanan	29021	Corn
73	Lincolnland Agri-Energy LLC	Palestine	IL	Crawford	17033	Corn
74	Lincolnway Energy LLC	Nevada	IA	Story	19169	Corn
75	Little Sioux Corn Processors LP	Marcus	IA	Cherokee	19035	Corn
76	MGP Ingredients Inc. (year 2002: name was Midwest Grain)	Pekin	IL	Tazewell	17179	Corn / Wheat Starch
77	MGP Ingredients Inc.(year 2002: name was Midwest Grain)	Atchison	KS	Atchison	20005	Corn / Wheat Starch
78	Michigan Ethanol, LLC (Poet)	Caro	MI	Tuscola	26157	corn
79	Mid-Missouri Energy Inc.	Malta Bend	MO	Saline	29195	Corn
80	Midwest Grain Processors	Lakota	IA	Kossuth	19109	Corn
81	Midwest Renewable Energy LLC	Sutherland	NE	Lincoln	31111	Corn
82	Minnesota Corn Processors	Marshall	MN	Lyon	27083	Corn
83	Minnesota Corn Processors	Columbus	NE	Platte	31141	Corn
84	Minnesota Energy	Buffalo Lake	MN	Renville	27129	Corn
85	Missouri Ethanol, LLC (Poet)	Ladonia	MO	Audrain	29007	Corn
86	New Energy Corp.	South Bend	IN	St Joseph	18141	Corn
87	North Country Ethanol, LLC	Rosholt	SD	Roberts	46109	Corn
88	Northeast Missouri Grain, LLC (Poet)	Macon	MO	Macon	29121	Corn
89	Northern Lights Ethanol, LLC (Poet)	Big Stone City	SD	Grant	46051	Corn
90	Northstar Ethanol, LLE (Poet)	Lake Crystal	MN	Blue Earth	27013	Corn
91	Otter Creek Ethanol, LLC (Poet)	Ashton	IA	Osceola	19143	corn
92	Pacific Ethanol Inc.	Madera	CA	Madera	6039	Corn
93	Pacific Ethanol Inc.	Boardman	OR	Morrow	41049	Corn
94	Phoenix Biofuels	Goshen	CA	Tulare	6107	corn
95	Pinal Energy, LLC	Maricopa	AZ	Pinal	4021	Corn
96	Pine Lake Corn Processors LP	Steamboat Rock	IA	Hardin	19083	Corn
97	Platte Valley Fuel Ethanol, LLC	Central City	NE	Merrick	31121	Corn Seed
98	Plover Ethanol	Plover	WI	Portage	55097	Corn/Potatoes
99	Poet, Portland	Portland	IN	Jay	18075	Corn
100	Poet, Corning	Corning	IA	Adams	19003	Corn
101	Poet, Glenville	Glenville	MN	Freeborn	27047	Corn
102	Poet, Leipsic	Leipsic	OH	Putnam	39137	Corn

Appendix 1. Continued

103	Poet,Mitchell	Mitchell	SD	Davison	46035	Corn
104	Prairie Ethanol, LLC	Loomis	SD	Davison	46035	Corn
105	Prairie Horizon Agri-Energy LLC	Phillipsburg	KS	Phillips	20147	milo/corn
106	Pro-Corn, LLC (Poet)	Preston	MN	Fillmore	27045	Corn
107	Quad County Corn Processors	Galva	IA	Ida	19093	Corn
108	Red Trail Energy LLC	Richardton	ND	Stark	38089	Corn
109	Redfield Energy, LLC	Redfield	SD	Spink	46115	Corn
110	Reeve Agri Energy	Garden City Jefferson Junction	KS	Finney	20055	Corn/milo
111	Renew Energy Renova Energy (Wyoming Ethanol)	Torrington	WY	Goshen	55055	Corn
112	Sioux River Ethanol, LLC (Poet)	Hudson	SD	Lincoln	56015	Corn
113	Siouxland Energy & Livestock Co-op	Hudson	SD	Lincoln	46083	Corn
114	Siouxland Ethanol, LLC	Sioux Center	IA	Sioux	19167	Corn
115	Sterling Ethanol LLC	Jackson	NE	Dakota	31043	Corn
116	Sterling Ethanol LLC	Sterling	CO	Logan	8075	Corn
117	Sunrise Energy	Blairstown	IA	Benton	19011	Corn
118	Sutherland Associates	Sutherland	NE	Lincoln	31111	Corn
119	Tall Corn Ethanol, LLC (Poet)	Coon Rapids	IA	Carroll	19027	corn
120	Tate & Lyle The Andersons Albion Ethanol LLC	Loudon	TN	Loudon	47105	Corn
121	The Andersons Clymers Ethanol, LLC	Albion	MI	Calhoun	26025	Corn
122	Trenton Agri Products LLC	Clymers	IN	Cass	18017	Corn
123	Tri-State Ethanol Co., LLC	Trenton	NE	Hitchcock	31087	Corn / Milo
124	United Ethanol	Rosholt	SD	Roberts	46109	Corn
125	United WI Grain Processors	Milton	WI	Rock	55105	Corn
126	Utica Energy, LLC	Columbus	WI	Columbia	55021	Corn
127	VeraSun Albert City LLC (Merge w/ US Bio in 2008)	Oshkosh	WI	Winnebago	55139	Corn
128	VeraSun Albion LLC	Albion	NE	Boone	19015	corn
129	VeraSun Albion LLC	Albert City Aurora/ Brookings	IA	Buena Vista	19021	corn
130	VeraSun Aurora LLC	Brookings	SD	Brookings	46011	Corn
131	VeraSun Central City LLC (Merge w/ US Bio in 2008)	Central City	NE	Merrick	31121	Corn
132	VeraSun Energy Forth Dodge	Fort Dodge	IA	Webster	19187	Corn
133	VeraSun Linden LLC	Linden	IA	Dallas	19049	corn
134	VeraSun Ord (Merge w/ US Bio in 2008)	Ord	NE	Valley	31175	Corn
135	VerSun Charles City LLC	Charles City	IA	Floyd	19067	Corn
136	Voyager Ethanol, LLC (Poet)	Emmetsburg	IA	Palo Alto	19147	corn
137	Western New York Energy, LLC	Shelby	NY	Orleans	36073	Corn
138	Western Plains Energy LLC	Campus	KS	Logan	20109	Corn
139	Western Wisconsin Renewable Energy, LLC	Boyceville	WI	Dunn	55033	Corn
140	White Energy	Hereford	TX	Deaf Smith	48117	Corn /Milo
141	Xethanol BioFuels, LLC	Blairstown	IA	Benton	19011	corn

Appendix 1. Continued

142	Yuma Ethanol	Yuma	CO	Yuma	8125	Corn
143	78th Street Ethanol, LLC	Blairstown	IA	Benton	19011	Corn