The Land-use Change Effect of Ethanol Plants in Iowa: 1997-2009

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Abstract

In this article we test the local land-use change effects of ethanol plants in Iowa using county-level panel data between 1997 and 2009. Results show that the establishment of ethanol plants has a significant effect on land-use change in counties where the plants are located. Moreover, locally owned ethanol plants have slightly higher effects than non-locally owned ethanol plants have. Specifically, *ceteris paribus*, the average effect of a locally (or non-locally) owned 100-million gallon ethanol plant is to increase the corn acreage share by 5.9 (or 5.7) percentage points in its host-county if the plant's corn supply area (defined as a round area center at the plant) is completely in the county. The land-use change effect is greater in counties with medium corn share than in counties with either low or high corn shares. Once rotation effects are controlled, the average prices in April for December corn future contracts no longer significantly affect corn acreage share.

Key words: land-use change, ethanol plants, Iowa, Arellano-Bond difference GMM estimator.

JEL classification: Q15, Q16, C50.

Introduction

The first decade of 21th century witnessed a world-wide surge of fuel ethanol (ethanol hereafter) production. The ethanol production in the world increased from 4.6 billion gallons in 2000 to 20.3 billion gallons in 2009.[1] The United States, due to its abundance of corn, is the leading producer and possesses about one half of world ethanol production capacity (RFA 2010). As of January 2010, there were 189 ethanol plants online in the United States (RFA 2010). The average capacity of these plants is 63 million gallons. Assuming the conversion rate from corn to ethanol is 1 bushel of corn producing 2.8 gallons of ethanol, then one average ethanol plant would annually consume 22.4 million bushels of corn.[2] If we further assume that the corn yield is 170 bu/acre, then every year a typical ethanol plant would need about 132,000 acres of cropland to supply feedstock to it. One question naturally arising here is whether, and to what extent, the appearance of ethanol plants has a direct effect on land-use. Intuitively, *ceteris paribus*, land near an ethanol plant is more likely to be devoted to growing corn, the major feedstock of ethanol plants, because it is close to the terminal markets (i.e., ethanol plants). Testing this hypothesis and estimating the magnitude of this effect are the focus of this article. The reasons why this work is of interest are as follows.

First, the answer to this question has important environmental implications since land-use change will induce changes in greenhouse gas emissions as well as changes in agricultural chemical applications, which would cause new environmental problems (Li and Feng 2008; Donner and Kucharik 2008). By precisely specifying whether, and to what extent, the land-use change occurs because of the establishment of ethanol plants, we can further precisely measure the environmental consequences (i.e., greenhouse gas emissions and change of agricultural chemical applications) of the expansion of the ethanol industry. This is of policy interest because if the area around ethanol plants experiences higher magnitudes of land-use change, then more effort to improve agricultural management should go to such an area in order to mitigate the environmental effects of land-use

[1] Source: U.S. Energy Information Administration.

[2] In 2009, the United States produced 10.6 billion gallons of ethanol by using 3.8 billion bushels of corn (RFA 2010). The conversion rate is 2.79.

change.

Second, there is still no consent as to whether the ethanol plants have effects on local grain prices (Lewis 2010; Katchova 2009; Gallagher *et al.* 2005; McNew and Griffith 2005) and on cropland values (Henderson and Gloy 2008; Du *et al.* 2007). By answering the question as to whether the ethanol plants affect land-use change, we can contribute to addressing these controversies by adding a supply-side dimension. This dimension could deepen our understanding of the relationship between ethanol plants and local grain prices as well as the relationship between ethanol plants and cropland values. For example, suppose one study (e.g., Katchova 2009) shows that the establishment of an ethanol plant does not affect the local corn prices. This relationship may be a result of a situation in which ethanol plants affect neither local corn demand nor supply; or a situation in which ethanol plants affect both local corn demand and supply but the effects of demand and supply offset each other. Studying the land-use change effect of ethanol plants could shed light on the issue about the relationship between ethanol plants and local grain prices, and hence local land values.

There is a large amount of literature on land-use change (e.g., Wu and Segerson, 1995; Miller and Plantinga, 1999; Lubowski *et al.*, 2008) and recently the land-use change effect of ethanol production has been attracting more and more attention since Searchinger *et al.* (2008) and Fargione *et al.* (2008) published their work on *Science*. However, there are few research on the direct land-use change effect of ethanol plants. Li and Feng (2008) studied the effect of surging ethanol production on land-use change due to the induced increasing demand of corn. Keeney and Hertel (2009) applied a computable general equilibrium model to simulate the land-use change effects of biofuels. Feng and Babcock (2010) developed a simple and elegant theoretical framework that incorporates market equilibrium responses to biofuel production, by which the authors analyzed the land-use change patterns in response to an increase in ethanol demand resulting either from market or from policy.

Many studies have examined the local impacts of ethanol plants. The majority of these studies focused on the effects of ethanol plants on local grain prices and local land values. But few of them studied the impact of ethanol plants on local land-use change. Currently there is no consent on whether ethanol plants have significant effects on local grain prices and on land values. Gallagher *et al.* (2005) showed that the relationship between ethanol plants and local grain prices depends on the ownership of the ethanol plants and the pricing system. McNew and Griffith (2005) examined the impact on local grain prices of 12 plants opened from 2001 to 2002. They found that the new ethanol plants increased local corn prices. However, O'Brien (2009) and Katchova (2009) did not find that ethanol plants have a positive effect on local corn prices. Lewis (2010) studied the relationship between ethanol plants and local corn prices in Iowa, Michigan, Kansas, and Indiana between 1998 and 2008. She found that the effect of ethanol plants on local corn prices varies across geographical regions. That is, the ethanol plants have a positive effect on local corn prices in Michigan and Kansas while such positive effect is not significant in Iowa and Indiana. Du *et al.* (2007) studied the effect of ethanol production on Iowa cropland cash rental rates. They concluded that the ethanol plants do not have an effect on the cash rental rates of the land around them. However, Henderson and Gloy (2009) found that ethnol plants increased land values.

The closest study to this article is Turnquist *et al.* (2008), in which the authors studied the effect of ethanol plants on the change in agricultural acreage and on the residential land values using data from Wisconsin. Their results showed that both the agricultural acreage changes and residential land values were not affected by the ethanol plants from 2000 to 2006 in Wisconsin. Instead of focusing on aggregate agricultural acreage change, we focus on the land-use change within the agricultural sector and study the effect of ethanol plants on the corn acreage share. Our analysis focuses on the state of Iowa because Iowa is on the frontier of ethanol production in the United States and has experienced significant expansion in ethanol industry (Figures 1 and 2). As of January 2010, Iowa hosted 41 ethanol plants with total nameplate production capacity of 3.3 billion gallons, which accounted for about 27% of the total production in the United States (RFA 2010). Using a panel data set that covers information of 41 ethanol plants between 1997 and 2009 in Iowa, we study the effect of ethanol plants on the corn acreage share while controlling for the effects of grain prices, grain yields, input prices, and crop rotations. Among the 41 plants, 11 of them are locally owned. Our results show that, *ceteris paribus*, locally owned ethanol plants have a slightly greater positive effect on land-use change than non-locally owned ethanol plants have. A county hosting a locally (non-locally) owned 100-million gallon ethanol plant has a corn acreage share that is 5.25 (or 5.07) percentage points higher than a county that does not hold such a plant, *ceteris paribus*. The land-use change effect is bigger in counties with medium corn share than in counties with either low or high corn shares. The corn acreage share in previous years has significant effects on the corn acreage share in the current year, which indicate a strong rotation effect. Once rotation effects are controlled, the average prices in April for December corn future contracts no longer significantly affect the corn share. Yields in the previous year have significant effects on the corn land share.

This paper proceeds as follows. In the next section we discuss the econometric model and data used for the analysis in this article. Then we analyze the results of the estimations. The last section concludes and discusses possible extensions of this article.

Methodology and Data

The purpose of our study is to quantify the local effect of ethanol plants on corn acreage share. Our hypothesis is that, *ceteris paribus*, the area in the vicinity of ethanol plants will be more likely to be subsequently planted with corn because the land is close to the possible terminal markets of corn (i.e., ethanol plants). Adhering to the literature of land allocation (e.g., Wu and Segerson, 1995; Miller and Plantinga, 1999), we assume that the county-level cropland share sufficiently reflects the individual land allocation decision. For simplicity, we only consider corn acreage share and compress all other crops into the "other crop" category.[3] Following Li and Feng (2008), the corn

[3]In Iowa, the "other crop" includes soybean, hay, corn for silage, oats, and wheat. During the period of 1997 to 2009, the average acreage share of the above four crops were 42%, 6%, 1%, 0.6%, and 0.1%, respectively. Source: calculated using data from NASS of USDA.

acreage share of county i at period t is determined by the following logit function:

$$s_{i,t} = \frac{e^{x_{i,t}\beta}}{e^{x_{i,t}\beta} + e^{x_{i,t}\gamma}}, \tag{1}$$

where $i = 1 \dots N$, $t = 1 \dots T$; $x_{i,t}$ is a $1 \times k$ vector of regressors; and β and γ are $k \times 1$ vectors of parameters for corn and other crop, respectively. In our study $N = 99$ and $T = 13$. The model can be identified if we normalize γ in equation (1) as 0. Then we get

$$s_{i,t} = \frac{e^{x_{i,t}\beta}}{e^{x_{i,t}\beta} + 1}. \tag{2}$$

After some algebra and then adding an error term which includes all other factors that affect crop shares, we have

$$ls_{i,t} \equiv ln(\frac{s_{i,t}}{1 - s_{i,t}}) = x_{i,t}\beta + \varepsilon_{i,t}. \tag{3}$$

In our study, the independent variables in $x_{i,t}$ are ethanol plant indices (i.e., $pil_{i,t}$ and $pinl_{i,t}$) that are to be explained below, corn prices (cp_t), soybean prices (sp_t), input price index ($ip_{i,t}$), lagged corn yields ($cy_{i,t-1}$), lagged soybean yields ($sy_{i,t-1}$), and lags of the dependent variable ($ls_{i,t-l}$, $l = 1, 2, ...$). Table 1 presents explanations and a statistic summary of the independent variables. Therefore, equation (3) can be explicitly written as

(4)

$$ls_{i,t} = \sum_{j=1}^{l} \alpha_j ls_{i,t-j} + \beta_1 pil_{i,t} + \beta_2 pinl_{i,t} + \beta_3 cp_{i,t} + \beta_4 sp_{i,t} + \beta_5 cy_{i,t-1} + \beta_6 sy_{i,t-1} + \beta_7 ip_{i,t} + a_i + e_{i,t},$$

where l is the maximum number of lags of the dependent variable; a_i is the unobserved time-constant variable for county i; and $\varepsilon_{i,t} \equiv a_i + e_{i,t}$.

Some econometric issues need to be addressed before we estimate equation (4). The first issue is simultaneous causality. We are interested in the causality that runs from ethanol plants to the corn acreage decision. But the causality may also run in the opposite direction. That is, ethanol plants would locate in areas with higher concentrations of corn production. For example, Iowa, the number one corn producing state in the United States, hosts the largest amount of ethanol plants. Within Iowa, most ethanol plants are located in areas with higher corn acreage (Figure 3). This means that independent variables *pil* and *pinl* are endogenous. The second problem is autocorrelation caused by including lagged dependent variables. Due to crop rotations, corn acreage decisions in year t are affected by the corn acreage decisions in year $t-1$, which were affected by the corn acreage decisions in year $t-2$, and so on. Including lagged dependent variables in the right side of equation (4) is logical but can lead to the problem of autocorrelation. The third one is that the time-constant variable, a_i, may be correlated with the independent variables. For example, the land quality in one county largely determines grain yields in that county. The fourth issue is that the data set used in this study has relative large panels ($N = 99$) and a small time range ($T = 13$).

To address the above econometric issues we apply the Arellano-Bond difference GMM estimator (AB estimator hereafter) developed by Holtz-Eakin *et al.* (1988) and Arellano and Bond (1991). The AB estimator uses first-difference to eliminate the time-constant variable, which handles the third issue discussed in the above paragraph. Then the AB estimator uses the level or difference of further lagged dependent variables as instruments of lagged dependent variables that appear in the right side of the econometric model. It also uses levels of lagged endogenous variables as instruments for corresponding endogenous variables. Additional instrumental variables can be applied for endogenous variables as well. Therefore, it handles the first and the second econometric issues listed in the above paragraph. In this article we use the aggregate locally owned ethanol production capacity in Iowa (i.e., pil_{sum}) and aggregate non-locally owned ethanol production capacity in Iowa (i.e., $pinl_{sum}$) as additional instruments of the two endogenous variables in our model, *pil* and *pinl*, respectively. The aggregate ethanol capacity is correlated with county level ethanol capacity but does not depend on an individual county.[4] Another benefit of using the AB estimator is that it

[4]Detailed discussion on using aggregate-level variables as instruments can be found on page 133 of Wooldridge (2002). An example that is close to the instruments in this article is Mileva (2008), in which the author used the ratio of aggregate long-term capital inflow of the sampled countries over the sum of the GDP of these countries as an instrument of individual country's capital inflow.

is appropriate for panel data that have a short time range but a large number of panels (Roodman 2009).

The data set used in this article is a balanced panel data set. It includes data of 99 counties in Iowa from 1997 to 2009. The corn acreage share, $s_{i,t}$, which is calculated by dividing the harvested acreage of corn by the total harvested acreage of county i in year t. The independent variable of interest in this study is the ethanol plant indices of each county in each year. Since there are locally owned ethanol plants and non-locally owned plants, we develop two ethanol plant indices for each county in each year. One is an index of locally owned plants, pil; the other is an index of non-locally owned plants, $pinl$. Ownership switch from locally owned to non-locally owned is not observed in our sample, even though two plants did experience ownership change in 2008.

The method to calculate $pil_{i,t}$ and $pinl_{i,t}$ is as follows. Here we only illustrate how to calculate $pil_{i,t}$. Calculating $pinl_{i,t}$ is exactly the same. First, for a locally owned ethanol plant, EP_j, $j = 1\ldots 11$, we calculate its corn supply area in year t, $SA_{j,t}$, by

$$SA_{j,t} = \frac{2 \times 10^6 C_{j,t}}{2.8 \times 170 \times 640}, \tag{5}$$

where $C_{j,t}$ is the nameplate capacity (unit: million gallons) of plant j in year t. If plant j does not exist in year t, then $C_{j,t} = 0$. In the denominator of equation (5), 2.8 gallons/bushel is the conversion rate from corn to ethanol; 170 bushels/acre is the assumed corn yield; and 640 is used to convert acres to square miles. In the numerator of equation (5), the number 2 means corn acreage share in the supply area is assumed at 50%. The values of these parameters in equation (5) do not matter very much for our purpose due to reasons that will be obvious once we finish describing the entire procedure. Second, following the tradition in the literature of ethanol plants' spatial effects, we assume the corn supply area of an ethanol plant is round and centered at the plant. The radius of the supply can be readily calculated. Third, by applying ArcMap software we measure the part of the supply area that is in the range of county i, $p^i_{j,t}$. Fourth, by applying equation (5) again we convert $p^i_{j,t}$ back into ethanol production capacity that affects county i, $C^i_{j,t}$. Therefore, we can see the parameters in equation (5) do not matter very much to our purpose since the equation only works as a convertor between capacity and affected land area. Fifth, in year t, the total ethanol capacity that affects county i is

$$pil_{i,t} = \sum_{j=1}^{11} C^i_{j,t}. \tag{6}$$

The same procedure applies to calculate $pinl_{i,t}$.

The independent variables also include one-year lagged corn yield, one-year lagged soybean yield, expected corn price, expected soybean price, and input price. The yields are obtained from National Agricultural Statistic Service (NASS) of U.S. Department of Agriculture (USDA). Expected corn (or soybean) price is calculated by averaging prices in April for December (or November) corn (or soybean) futures. The corn and soybean future prices are observed from Chicago Mercantile Exchange (CME). The input price is obtained from Table 8 of "U.S. Fertilizer Use and Price" data set published by Economic Research Service (ERS) of USDA.[5] The price data are not county specific. That is, in period t corn prices (or soybean prices, or input prices) across counties are the same.

Empirical Analysis

The AB estimations of regression (4) are implemented by "xtabond" command of Stata 11. The lag order of the dependent variable is set at 2. Regression (4) with $l = 2$ passes the Arellano-Bond test (AB test hereafter) for zero autocorrelation in first-differenced errors. However, if $l = 1$, then the model does not pass the AB test for zero autocorrelation. The model passes the AB test when $l = 3$ but the third order lag does not significantly affect the dependent variable. The AB estimations of model (4) when $l = 1$, 2, or 3 are presented in columns (1) to (3) in Table 2, respectively. Since the first-differenced errors in periods t and $t-1$ both include $e_{i,t-1}$, there must be AR(1) in the

[5] Website: http://www.ers.usda.gov/Data/FertilizerUse/. Accessed Dec 2, 2010.

first-differenced errors. As expected, the AB test for AR(1) in first-differenced errors rejects the null hypothesis that there is no autocorrelation (the second to last row in Table 2). Therefore, we cannot conclude that there is autocorrelation in idiosyncratic errors just based on the rejections of AB test for AR(1) in the first-differenced errors. AB test for AR(2) in first-differenced errors are applied to determine the autocorrelation in idiosyncratic errors. The last row in Table 2 shows the p-values of AB test for AR(2), which indicate there is autocorrelation in idiosyncratic errors when $l = 1$. When $l = 2$ or 3, the AB test for AR(2) in first-differenced errors does not reject the null hypothesis that there is no autocorrelation in idiosyncratic errors.

Columns (4) to (6) contain results of fixed effects estimations of regression (4). We report results from fixed effects estimations because we are interested in what the estimations would be if we were not to use AB estimations to correct the econometric problems of regression (4) we discussed in the last section. Column (4) contains the results of fixed effects estimation when $pil_{i,t}$ (or $pinl_{i,t}$) is instrumented by its first order lag and by total locally owned (or non-locally owned) ethanol production capacity in Iowa. Column (5) contains the results of fixed effects estimation that treats each independent variable as exogenous. Column (6) reports the results of fixed effects estimation that excludes the lags of dependent variables as explanatory variables and treats each independent variable as exogenous.

Table 2 shows that in each estimation from columns (1) to (6) the establishment of ethanol plants in one county has significantly positive effects on corn cropland share. Especially, in the AB estimations (i.e., columns (1) to (3)) the coefficients of $pil_{i,t}$ and $pinl_{i,t}$ are significant at 1% level. The preferred estimation (column (2) in Table 2) indicates that if the corn supply area of one locally (or non-locally) owned 100-million gallon ethanol plant is completely within one county, then the ratio between corn acreage share and other crop acreage share will be increased by 27% (or 26%) due to the ethanol plant coming online. For example, if the corn acreage share in this county is 50% (i.e., the average corn acreage in the data set) before the 100-million gallon locally owned (or non-locally owned) ethanol plant is online, then the corn acreage share in this county will be increased to 55.9% (or 55.7%) after this ethanol plant is online.[6] We notice that the locally owned ethanol plants have slightly higher land-use effect than non-locally owned ethanol plants do. One possible explanation for this conclusion is that some of the locally owned ethanol plants only purchase corn from its farm owners (McNew and Griffith, 2005).

One result arising from the construction of the dependent variable is that the corn acreage share change is greater in counties with medium corn share than in counties with either low or high corn shares (Appendix A). This is intuitive because an initially low corn acreage share indicates that counties with such a share may not be very productive in corn and hence have little incentive to increase corn acreage share. On the other hand, if a county has a very high corn acreage share before the establishment of ethanol plants, then this county may have little space to respond to the impact of ethanol plants. However, counties with medium corn acreage shares can sufficiently respond to the emergence of an ethanol plant.

The long-run effects can be calculated by using the estimates in column (2) in Table 2. By setting $ls_{i,t} = ls_{i,t-1} = ls_{i,t-2}$ and then rearranging equation (4), we can obtain the long-run effects of locally owned ethanol plants as

$$\beta_{pil}^{lr} = \frac{\beta_1}{1 - \alpha_1 - \alpha_2}. \tag{7}$$

Plugging corresponding coefficients from column (2) into equation (7), then we obtain $\beta_{pil}^{lr} = 0.0026$. Similarly, we can also calculate the long-run effect of non-locally owned ethanol plants, which is $\beta_{pinl}^{lr} = 0.0025$.

Each estimation presented in Table (2) shows that the coefficients of lags of the dependent variable are significant at the 1% significance level. Specifically, the first-order lag of $ls_{i,t}$ has a negative effect on the dependent variable and the second-order lag of $ls_{i,t}$ has a positive effect on the dependent variable. This is intuitive because corn is usually planted in a corn-soybean

[6] The algebra to obtain 56% is as follows. If corn acreage share is 50%, then the ratio between corn acreage share and other crop share is 1. The new ratio after the ethanol plant is online will be 1.27. Suppose the new share of corn acreage is $s\prime$. Then solve equation $s\prime/(1-s\prime) = 1.27$ generate $s\prime = 55.9\%$.

rotation in Iowa. Therefore, one year with higher corn share usually indicates that the next year will have a higher soybean acreage share and a lower corn acreage share relative to the previous year. Interestingly, once we control the first two lags of the dependent variable, the expected corn price no longer significantly affects corn, from which we can conclude that the rotation effect is stronger than expected prices in determining the corn cropland share. One explanation could be that in our sample the benefit of corn price change did not surpass the benefit of following the corn-soybean rotation. The coefficient of input price is positive and statistically significant in each estimation. The lagged corn yield has a significant positive effect on corn cropland in each estimation in columns (1) to (6) in Table 2. In the preferred estimation (column (2)), *ceteris peribus*, if corn yield is increased by 10 bushels per acre, then the ratio between corn cropland and other cropland will be increased by 2.2%.

Conclusions and Discussions

We study the land-use change effect of ethanol plants in Iowa from 1997 to 2009 by applying a logit land share model. AB estimation is applied to fix the econometric problems of the model (i.e., autocorrelation, endogeneity, unobserved time-constant variables, and the size of the sample). Using county level panel data consisting of the share of corn, indices of ethanol plant, the expected price of corn and soybeans, and the input price index, our empirical analysis shows that the existence of ethanol plants has a significant effect on land-use change in a county. In particular, locally owned ethanol plants have slightly higher effects than non-locally owned ethanol plants do. The land-use change effect is larger in counties with medium corn share than in counties with either low or high corn shares. Once rotation effects are controlled, the average prices in April for December corn future contracts no longer significantly affect corn acreage share.

Once the relationship between ethanol plants and local land-use change is established, one can further estimate the direct environmental effect from the land-use change caused by the establishment of ethanol plants. This could make the system-wide accounting (Feng *et al.* 2010) of greenhouse gas impacts of the corn-based ethanol more precise. Moreover, this analysis could provide a quantitative basis for estimating other environmental impacts of corn-based ethanol industry, such as water quality impact due to land-use change caused by ethanol plants. Our analysis in this article also sheds light on understanding the relationship between ethanol plants and local grain prices as well as the relationship between ethanol plants and local land values by providing a supply dimension perspective. One meaningful expansion of this study is to enlarge the sample to include all 189 ethanol plants currently in existence in the United States as of January, 2010. This expansion would allow a comprehensive study of the economic and environmental impacts of the corn-based ethanol industry in the United States.

Appendix

In this Appendix we show how to reach the conclusion that the corn acreage share change is bigger in counties with medium corn share than in counties with either low or high corn shares. Suppose corn acreage shares are s and $s\prime$ in one county before and after a 100-million gallon ethanol plant comes online, respectively. And suppose the land-use change impact of this ethanol plant to the county is $\hat{\beta} > 0$, which can be obtained from the estimation of regression (4). Then s, $s\prime$, and $\hat{\beta}$ should be such that

(A-1)
$$\frac{s\prime}{1-s\prime} = \frac{s}{1-s}(1+100\hat{\beta}).$$

Then we have

(A-2)
$$\begin{aligned} s\prime &= \frac{\frac{s}{1-s}(1+100\hat{\beta})}{1+\frac{s}{1-s}(1+100\hat{\beta})} \\ &= \frac{s(1+100\hat{\beta})}{1-s+s(1+100\hat{\beta})} \\ &= \frac{s+100\hat{\beta}s}{1+100\hat{\beta}s}. \end{aligned}$$

Therefore, the corn acreage share change is

$$\text{(A-3)} \qquad \begin{aligned} \Delta s \equiv s\prime - s &= \frac{s + 100\hat{\beta}s}{1 + 100\hat{\beta}s} - s \\ &= \frac{s + 100\hat{\beta}s - s - 100\hat{\beta}s^2}{1 + 100\hat{\beta}s} \\ &= 100\hat{\beta}\frac{s(1-s)}{1 + 100\hat{\beta}s}. \end{aligned}$$

Taking derivative of Δs with respect to s,

$$\text{(A-4)} \qquad \begin{aligned} \frac{d\Delta s}{ds} &= 100\hat{\beta}\frac{(1-2s)(1+100\hat{\beta}s) - 100\hat{\beta}(s-s^2)}{(1+100\hat{\beta}s)^2} \\ &= 100\hat{\beta}\frac{-100\hat{\beta}s^2 - 2s + 1}{(1+100\hat{\beta}s)^2}. \end{aligned}$$

The two roots of the quadratic equation $-100\hat{\beta}s^2 - 2s + 1 = 0$ are $\frac{-1 \pm \sqrt{1+100\hat{\beta}}}{100\hat{\beta}}$. Since corn acreage shares are always non-negative, we only need to focus on the positive root, $\frac{-1+\sqrt{1+100\hat{\beta}}}{100\hat{\beta}}$. It is readily to check that $\frac{-1+\sqrt{1+100\hat{\beta}}}{100\hat{\beta}} < 1$ given $\hat{\beta} > 0$. It is clear that $-100\hat{\beta}s^2 - 2s + 1 > 0$ and hence $\frac{d\Delta s}{ds} > 0$ when $s \in [0, \frac{-1+\sqrt{1+100\hat{\beta}}}{100\hat{\beta}})$. When $s \in (\frac{-1+\sqrt{1+100\hat{\beta}}}{100\hat{\beta}}, 1]$, however, then $-100\hat{\beta}s^2 - 2s + 1 < 0$ and hence $\frac{d\Delta s}{ds} < 0$.

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Table 1. Variables: Explanation and Statistic Summary

(Observations: 1287)

Variable	Explanation	Mean	Std. Dev.	Min	Max
ls	log of the ratio between corn acreage share and other crop acreage share	-0.11	0.30	-1.35	0.92
pil	plant index of locally owned ethanol plants	2.06	9.58	0	75.38
pinl	plant index of non-locally owned ethanol plants	8.90	20.01	0	229.19
cy	corn yield	154.06	20.40	88.8	198.5
sy	soybean yield	45.76	6.48	23.1	60.8
cp	expected corn price	305.04	105.94	220.24	613.47
sp	expected soybean price	669.27	209.26	431.76	1236.78
ip	input price index	173	70.26	95	355

Table 2. Results of AB Estimations and Fixed Effects Estimations of Model (4)

	AB Estimations			Fixed Effects Estimations		
independent variable	(1)	(2)	(3)	(4)	(5)	(6)
$ls_{i,t-1}$	-0.5007***	-0.3922***	-0.4750***	-0.1350***	-0.1119***	---
	(0.0733)	(0.0654)	(0.0862)	(0.0433)	(0.0426)	
$ls_{i,t-2}$	---	0.3554***	0.3601***	0.4529***	0.5008***	---
		(0.0495)	(0.0544)	(0.0339)	(0.0320)	
$ls_{i,t-3}$	---	---	-0.0454	---	---	---
			(0.0574)			
$pil_{i,t}$	0.0042***	0.0027***	0.0029***	0.0012**	0.0008*	0.0017***
	(0.0013)	(0.0010)	(0.0011)	(0.0005)	(0.0004)	(0.0004)
$pinl_{i,t}$	0.0049***	0.0026***	0.0028***	0.0023***	0.0011***	0.0025***
	(0.0011)	(0.0009)	(0.0010)	(0.0004)	(0.0003)	(0.0003)
$cy_{i,t-1}$	0.0011***	0.0022***	0.0022***	0.0023***	0.0023***	0.0015***
	(0.0003)	(0.0004)	(0.0004)	(0.0003)	(0.0003)	(0.0003)
$sy_{i,t-1}$	0.0019**	-0.0009	-0.0010	-0.0025***	-0.0025***	-0.0008
	(0.0008)	(0.0007)	(0.0007)	(0.0008)	(0.0008)	(0.0007)
$cp_{i,t}$	-0.0004**	0.0002	0.0002	0.0002	0.0002	-0.0003*
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
$sp_{i,t}$	0.0004***	-0.0000	-0.0001	-0.0002	-0.0002*	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0000)
$ip_{i,t}$	0.0004**	0.0007***	0.0010***	0.0007***	0.0008***	0.0004**
	(0.0002)	(0.0001)	(0.0002)	(0.0002)	(0.0002)	(0.0001)
constant	---	---	---	-0.3492***	-0.3437***	-0.3760***
				(0.0485)	(0.0450)	(0.0438)
AB test for AR(1): p-value	0.0000	0.0000	0.0000	---	---	---
AB test for AR(2): p-value	0.0013	0.7169	0.8040	---	---	---

Notes: For columns (1) to (3), the robust standard errors are reported in parentheses. For columns (4) to (6), the standard errors are reported in parentheses. The AB test for autocorrelation in the last two rows is applied for first-differenced errors. Single, double, and triple asterisks (i.e., *, **, and ***) denote significance at 10%, 5%, and 1% levels, respectively.

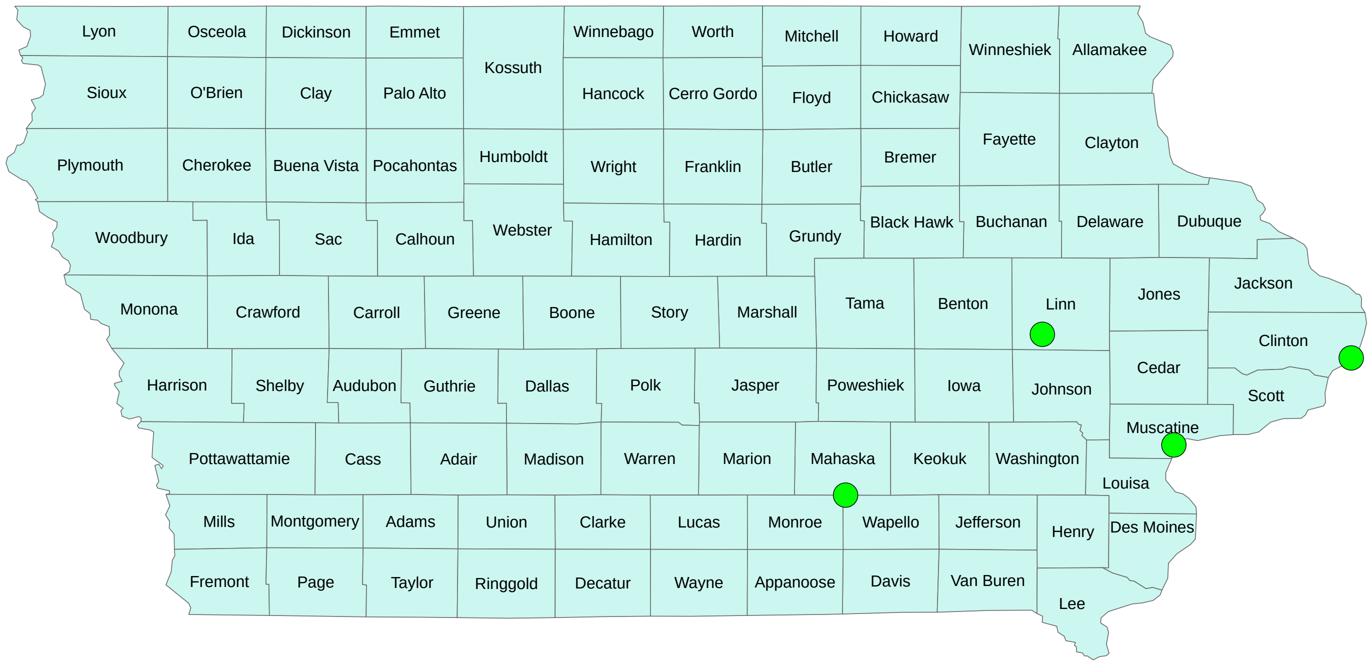

Figure 1. Ethanol Plants in Iowa: 1997

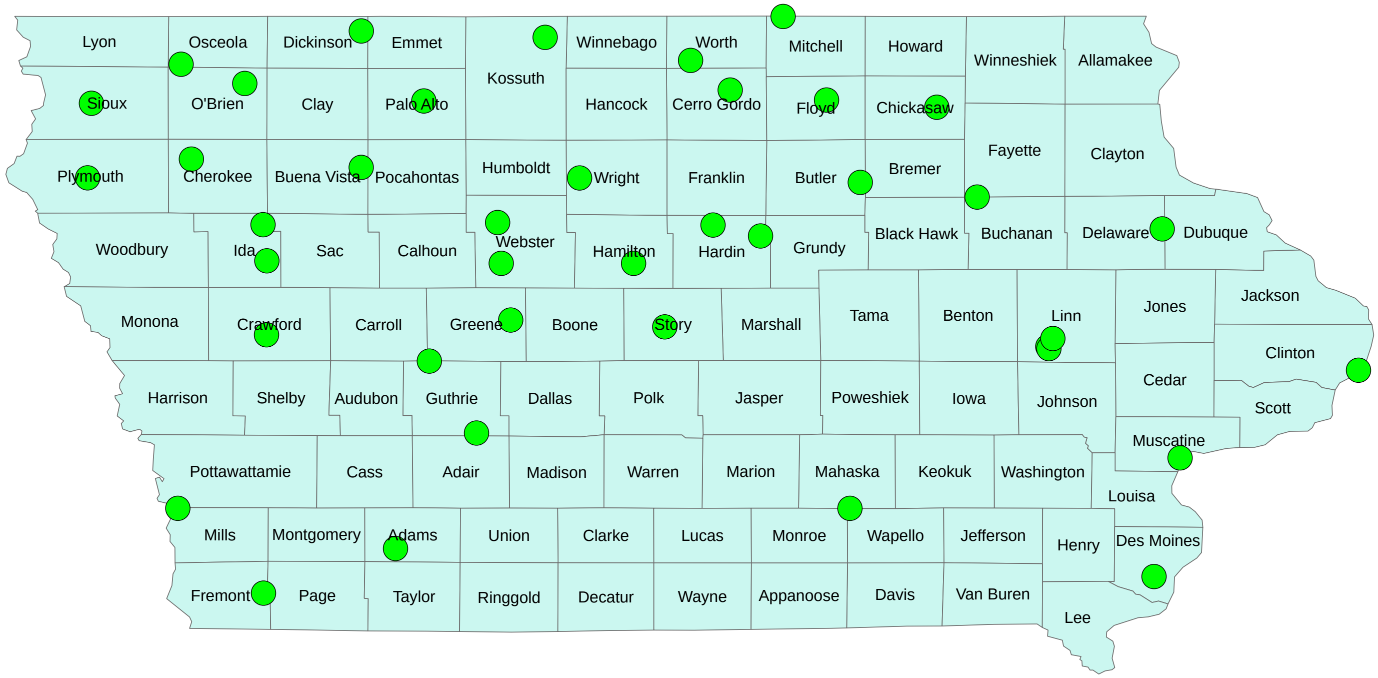

Figure 2. Ethanol Plants in Iowa: 2009

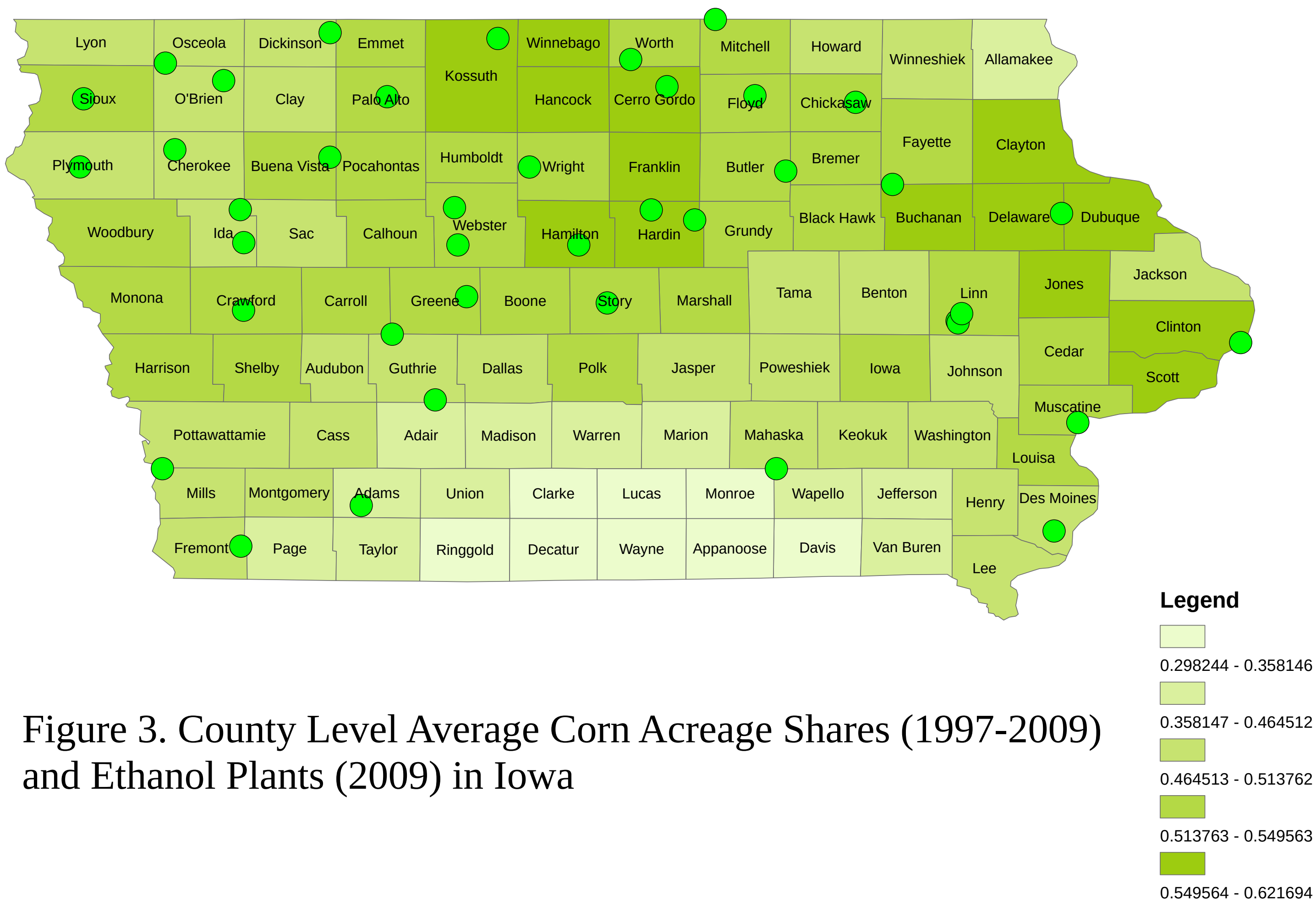

Figure 3. County Level Average Corn Acreage Shares (1997-2009) and Ethanol Plants (2009) in Iowa