Chapter 28
Modeling Ethanol Investment Decisions

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28.1 Introduction

Recently the support of biofuel production has been a politically sensitive topic. Politicians have pushed for support for fuel ethanol production as an environmentally friendly alternative to imported oil, as well as a way to boost farm profits and improve rural livelihoods. Several government policies actively promote ethanol production via tax incentives and mandates, and these policies are blamed for rising food prices around the world [14]. It is important to understand the factors that have motivated the significant local investments in the ethanol industry that have been made since the mid-1990s both in the U.S. and worldwide.

Fuel ethanol has been in use in the United States since the time of the Model T Ford (the original flex-fuel vehicle), and while the United States passed Brazil in ethanol production in 2005, today ethanol is mostly relegated to status as a gasoline additive. The first US ethanol boom began as a result of the oil embargoes in 1973 and 1979. The desire for more energy self-sufficiency, the resulting legislation (in the form of federal income tax credits and blender's credits that continue today), and the phase out of leaded gasoline led to the construction of 153 new plants by 1985 [4]. These plants were tiny by today's standards, with an average capacity of eight million gallons per year, and by 1991 only 35 were still operational due to poor business judgment and bad engineering [4, 18].

The second US ethanol boom began in the mid-1990s and hit full-stride by the early 2000s. Several factors contributed to this most recent boom. The Clean Air Act of 1990 mandated use of oxygenates in gasoline, of which ethanol is one, and the subsequent phase out and ban of MTBE as additive beginning in the late 1990s

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further increased demand for ethanol. Additionally the Renewable Fuel Standards of the Energy Policy Act of 2005 mandated ethanol production floors beginning in 2007, which rise to 36 billion gallons per year in 2033. Over this time period, the number of ethanol plants rose from 35 plants in 1991, to 50 in 1999, to 192 in September of 2010 for a total capacity of 13 billion gallons per year.

In addition to the policy and demand-side contributors to the recent ethanol boom, this new industry growth has been accompanied by changes in plant management and technology. Most significantly, the average capacity of plants in our focus region was 62 million gallons per year in 2008 up from 8 million gallons per year in 1985. In the mid-1990s the industry began designing more efficient plants, which use natural gas instead of coal as fuel [4]. Ownership is also shifting to streamlined corporate owners with multiple plants. Historically, farmer-owned plants had a large share of the market, though by 2007 only 11 % of new capacity was farmer owned, while the largest five corporations had 42 % of capacity in 2008 [6].

This recent boom, in addition to industry changes in technology and ownership structure, beg an analysis of investment decisions. Most ethanol plants use corn as a feedstock, and thus are located in the Midwestern United States, where the majority of the corn in the US is grown; these plants are the focus of our study. Since biofuels have been touted as a way to enhance profits in rural areas, where grain prices have remained stagnant over time, it is important to determine what factors affect decisions about when and where to invest in building new ethanol plants. In [11], we model this decision in this paper using both reduced-form and structural models.

Even when excluding the U.S., which was the country with the largest fuel-ethanol production in 2009, the fuel-ethanol industry has been growing rapidly in the rest of the world (ROW). Ethanol-producing countries in the ROW include Brazil, Canada, China, and Thailand, as well as countries in Europe. There are 191 fuel-ethanol plants in the ROW, which is a little more than in the U.S., and 82 % of them were built after 2005. In [12,13], we estimate a model of the investment timing game in ethanol plants worldwide that allows for the choice among different feedstocks.

In Europe, 20 countries have fuel ethanol production and most of the fuel ethanol plants were built after 2000. The development of European biofuel is based on two Directives: the Renewable Energy Directive (RED) of 2003/30/EC sets indicative targets of 2 % renewable fuels in transport by 2005 and 5.75 % by 2010 but is not legally binding, and the RED of 2009/28/EC is made mandatory and therefore legally binding. The main policies fuel ethanol policies in Europe include a tax credit, a blending mandate and R&D support. Most of the policies were implemented after 2003. Empirical research shows that the effects of policies for the U.S. fuel ethanol production are positive [9, 11, 17], however, whether the stimulation effects of the government policies play the same role in Europe is not yet clear, especially for the different varieties of feedstocks.

There is a related literature on food manufacturing location decisions which begins with a basic model of determinants of manufacturing establishment growth. One example is Goetz's [7] analysis of the determinants of rural food manufacturing establishment growth. He considers the effects of the following factors: access to output markets, labor force composition and quality, transportation infrastructure, government intervention, and availability of raw materials. In his model, location decisions involve a two-step process where regions are first chosen for broader consideration, and then the choice is narrowed within each region.

The decision to build a fuel ethanol plant involves a dynamic decision-making process. Investors have to consider the entire stream of per-period payoffs from now into the future. Because values of the state variables can change over time, for example if ethanol and feedstock prices change, or if there is a chance that neighboring plants might be constructed and start production, there is an option value to waiting that makes the decision dynamic rather than static.

When the decision of an investor is affected by neighbors' investment decisions, it becomes a more complicated decision-making problem. There are two types of effects that add a strategic (or non-cooperative) dimension to the potential entrants' investment timing decisions. The first type of effect is a competition effect, which arises if there is more than one ethanol plant located in one region so that these plants compete in feedstock supply when they choose the same feedstock or compete in local fuel ethanol market given limited demand. The competition effect deters ethanol plants for entering in regions where there are other ethanol plants already present. The second type of effect is an agglomeration effect: if there are several ethanol plants located in the same region, the existing plants may have developed transportation and marketing infrastructure and/or an educated work force that new plants can benefit from. The agglomeration effect induces an ethanol plant to locate near other plants, since a fuel ethanol plant benefits from the existence of other plants. Owing to both competition and agglomeration effects, the dynamic decision-making problem faced by the potential ethanol plants is not merely a single-agent problem, but rather can be viewed as a non-cooperative game in which plants behave strategically and base decisions on their neighbors' strategies.

There are few studies that specifically address the location determinants of ethanol plants in the United States and this is the first that econometrically models the entry location decision. Sarmiento and Wilson [17] use a cross-sectional discrete choice model to analyze agricultural characteristics and spatial dimensions that determine plant location. Similarly, Lambert et al. [9] use a cross-sectional discrete choice model spatial clustering to look at factors that affect the presence of ethanol plants and proposed plants in a given county, and also isolate clusters that may attract investment. Finally, Haddad et al. [8] model state-by-state spatial determinants of plant location, and find significant differences across states.

While these studies analyze similar factors as Goetz [7], they are cross-sectional and so cannot address investment timing decisions and thus only focus on location determinants, providing a starting point for our analysis as far as identifying potentially important exogenous factors. However, the results of these studies are not always qualitatively similar because of the different empirical specifications and regional foci. For example, the first two studies find that access to corn is an important location determinant. However, Haddad et al. [8] do not find access to corn significant, though they note that following location theory (see [7]), firms might choose a region with a lot of corn, and in the second stage will make their location decision based on other factors; this two-stage decision-making process is why they find differences in location determinants across states.

None of the studies adequately addresses the potential competition between plants in the location decision. Haddad et al. [8] do not include potential spatial competition between plants as an explanatory variable, perhaps since most competing plants are not located in the same county. Lambert et al. [9] include plants established before 2000 as an explanatory variable and find a negative impact on new plants and announcements between 2000 and 2007, though there is no analysis of spatial relationship or relative timing on those (potential) entrants. Sarmiento and Wilson [17] employ a cross-sectional model of plant location with a spatially lagged dependent variable in order to estimate the competitive effect between plants. They find a large negative effect of a nearby plant on the probability of another plant locating nearby, and furthermore, that this effect decreases with distance. It is important to note however that these competitive effects only describe the relationship between existing plants; neither of these models has a time element and without panel data it is not possible to analyze the effect of competition on entry.

This article reviews some of the papers my co-authors and I have written analyzing what factors affect the decision to invest in building new ethanol plants using a dynamic structural econometric model of the investment timing game. This work improves upon the previous literature by estimating a dynamic model with panel data, and by directly estimating the effect of covariates on the investment decision itself. The results of my research will help determine which policies and factors can promote fuel-ethanol industry development.

28.2 Theoretical Model

We model whether or not there is an investment in an ethanol plant i in county k in year t. Investment in an ethanol plant is irreversible and, in each year t, all investment decisions are made simultaneously. I_{ikt} is an indicator of whether there is an investment in a new ethanol plant i in county k in year t.

Because the profits from investing in building a new ethanol plant depend on market conditions such as feedstock price that vary stochastically over time, a potential entrant that hopes to make a dynamically optimal decision would need to account for the option value to waiting before making this irreversible investment [3]. The dynamic decision-making problem faced by a potential entrant is even more complicated when its profits are affected not only by exogenous market conditions, but also by the existence or potential entry of nearby plants.

The covariates X_{kt} describe the state of the input and output markets. The state variable a_{kt} is the number of other plants in the county. The investment decision in each county k in year t depends on the state of the county $\Omega_{kt} = (a_{kt}, X_{kt})$ through its effect on the profits from investing. The state variables a_{kt} and X_{kt} evolve according to a first-order Markov process and summarize the direct effect of the past on the current environment.

The profit from investing in an ethanol plant in year t is denoted by $\pi(a_{kt}, X_{kt})$, which is the expected revenue from the plant minus the expected costs. The value function for a potential entrant i in county k in period t can be written as:

$$V(a_{kt}, X_{kt}) = \max\{\pi(a_{kt}, X_{kt}), \beta V^c(a_{kt}, X_{kt}). \tag{28.1}$$

The payoff will depend on whether the potential entrant decides to wait and not build an ethanol plant in year t, indicated by $I_{ikt} = 0$, or to build an ethanol plant, indicated by $I_{ikt} = 1$. If the potential entrant chooses to build an ethanol plant in year τ, he will receive the payoff $\pi(a_{kt}, X_{kt})$. If the potential entrant chooses not to invest at time t, then he receives the discounted continuation value $\beta V^c(a_{kt}, X_{kt})$, where β is a discount rate, and $V^c(a_{kt}, X_{kt})$ is the continuation value to waiting. Whether or not there is a new investment depends on which of these options yield the highest payoff in that particular period.

The continuation value $V^c(a_{kt}, X_{kt})$ is the expected value of the next period's value function, conditional on not building an ethanol plant in the current period, and is given by:

$$V^c(a_{kt}, X_{kt}) = E\left[V(a_{k,t+1}, X_{k,t+1}) | a_{kt}, X_{kt}, I_{ikt} = 0\right]. \tag{28.2}$$

There will be a new investment in an ethanol plant i in county k in year t if the profits from the investment are greater than the continuation value from waiting.

The state variable a_{kt} represents the strategic interactions among plants. Plants located nearby have the potential to create positive and negative externalities for entering plants. In terms of positive externalities, such as agglomeration effects, there could be benefits for a new plant from taking advantage of the transportation or marketing infrastructure or the educated work force already developed by an existing plant (see e.g., [5, 7, 9]). In terms of negative (pecuniary) externalities, plants could compete in both the output and input markets. For example, Sarmiento and Wilson [17] explain that their estimated negative competitive effect is due to competition in feedstock procurement. If corn markets are localized a shift in demand from a new plant could cause increased prices.

The state variables in X_{kt} model the expected profits from the sale of ethanol, which include variables describing prices in the output market as well as the costs of production.

28.3 Econometric Methodology

In [11], we first estimate a reduced-form discrete choice model by regressing the probability of investment in an ethanol plant on the covariates using a fixed-effects logit model. It is logical to begin with the fixed-effects model since unobservable county characteristics might explain their ability to attract investment in an ethanol plant. The major advantage of a fixed-effects model is the addition of the county-specific effect. This allows us to control for unobservable county traits, such as openness to or promotion of business, that remain fixed over time. This is particularly important since the resolution of our data is not ideal and some variables are not observed at the county level. We next specify the strategic variable, other plants, as capacity instead of count. We hypothesize that larger or smaller competing capacities could have different effects. Third, we group the competing plants by type: singlets (plants that have no sister plant with the same owner), ethanol-only firms, and conglomerates. We hypothesize that different types of operators may produce different externalities (either positive and negative) towards potential entrants. We estimate a fourth model using entry of different type of plant (singlet, ethanol-only, and conglomerate) as the dependent variable in a pooled multinomial logit model.

In [11], we follow up the reduced-form models of investment in an ethanol plant with a structural model. We use a structural model for several reasons. First, it is interesting to estimate the effect of the state variable the expected payoff from investing in an ethanol plant. In the reduced-form model, we estimate the effect of these variables on the probability of investment. Second, the structural model makes it possible to estimate the strategic interaction between different regions that produce corn and could invest in ethanol plants. Thirdly, the structural model explicitly models the dynamic investment decision, including the continuation value to waiting. In contrast, the reduced-form model only estimates the per-period probability of investment.

As explained by Reiss and Wolak [16], a structural econometric model is one that combines economic theory with a statistical model, enabling us to estimate structural parameters. Incorporating firm dynamics into structural econometric models enhances our understanding of behavior and also enables us to estimate structural parameters which have a transparent interpretation within the theoretical model that frames the empirical investigation [1].

Dynamic discrete choice structural models are useful tools in the analysis of economic and social phenomena whenever strategic interactions are an important aspect of individual behavior. In the ethanol market, because a firm's costs and market demand hinge on the structure of market, a firm's decision depends on its conjecture about competitors' behavior. This type of model assumes agents are forward looking and maximize the expected discounted value of the entire stream of payoffs. Agents are assumed to make decisions based only on historic information directly related to current payoffs, and history only influences current decisions insofar as it impacts a state variable that summarize the direct influence of the past on current payoffs.

Recent papers have developed techniques for estimating dynamic games between multiple agents. Pakes et al. [15] illustrated a dynamic entry/exit game where the structural parameters could be estimated semi-parametrically. Bajari et al. [2] added to this literature by describing the estimation of the parameters in a dynamic game with continuous control variables.

In [11], we estimate a model of the investment timing game in corn ethanol plants in the United States. This model follows my previous work estimating a structural econometric model of the multi-stage dynamic investment timing game in offshore petroleum production [10], which is based on an econometric model developed by Pakes et al. [15]. In Lin [10], I build on the work of Pakes et al. [15] on discrete games of entry and exit by examining sequential investments with a finite horizon. The econometric estimation technique takes place in two steps. In the first step, the continuation value is estimated nonparametrically and used to form the model's estimate of the investment probabilities. In the second step, the investment probabilities predicted by the model are matched with the empirical investment probabilities in the data using generalized method of moments.

In [12, 13], we estimate a model of the investment timing game in ethanol plants worldwide that allows for the choice among different feedstocks. This research differs from previous studies of the investment and location of ethanol plants because it models the decision as a dynamic one rather than a static one, because it allows for the choice among multiple feedstocks rather than just one feedstock such as corn, because its strategic framework allows the estimation of strategic interactions among plants, and because it uses international data rather than data from the U.S.

28.4 Conclusions

The results of both the reduced-form and structural estimation in [11] indicate that there is an important strategic component to investment in ethanol plants. This net-negative effect may be due to localized competition, though we also find that plant identity matters as far as the strength and sign of this effect. We cannot explore the plant identity question (or exit) more in our current framework, but this is subject of ongoing work.

In [11], we also find that intensity of corn production is important in determining local investment in both models. Corn is bulky and transportation is not cheap, so it is beneficial for plants to locate where they have good access to feedstock.

In [11], we find mixed results of the effects of input and output prices across the different models and specifications. This inconsistency is potentially due to the data resolution, which, at state and national level, is not ideal. That said, we were still able to find some effect of prices indicating that (1) they do matter, and (2) even with less than ideal data source, our model is strong enough to tease out some of these effects.

In [11], we also find mixed results of the policy variables. In the reduced-form specification, we find that the state producer tax breaks are important, and the MTBE ban is significant in the structural model. The differences here may be due to the models themselves. The MTBE ban affects the market via increased ethanol demand and higher expected prices; thus in the structural model it leads to increased expected profits from investment. The producer support/tax break only applies to some plants, and only to some of the production, so we may not have identified this effect in the structural model, where the profit function is the same for each county. Further analysis of the effects of policies on investment in ethanol plants is subject of ongoing work.

In [12, 13], we first construct a dynamic discrete choice model for a potential fuel ethanol plant in which the investor maximizes its present discounted value of its entire stream of payoffs, and in which the decisions of other plants in the same local market affect an investor's decision.

The innovative features of our model are the consideration of interactions between fuel ethanol plants and the dynamic decision making framework. Once the dynamic decision making process has been fully described, the effects of economic, policy and strategic variables on profit can be estimated through a semiparametric approach.

Our results in [13] show that the potential investor considers various exogenous conditions: higher ethanol prices, gasoline prices, plenty of feedstocks and government support are very helpful to improve the profits, while a high natural gas price would harm the profits although some of the coefficients on natural gas are not significant. The negative competition effects of livestock vary across the choices of feedstocks. There is a negative effect on profits for all types of fuel ethanol plants which come from existing plants. In addition, the strategic interactions resulting from competition and agglomeration effects from other potential entrants are not obvious.

Thus, according to our results, we find that, in the United States, competition between plants is enough to deter local investments. We also find that availability of feedstock is important in determining plant location. We also find that in the United States state producer tax credits and the federal MTBE ban have a positive effect on ethanol investment [11]. In Europe, competition between plants deters local investments and ethanol support policies encourage investments [13]. In Canada, competition between plants is enough to deter local investments, the availability of feedstock is important in determining plant location, and the effects of policy support for wheat-based plants are significant [12].

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