Title
Ethanol Plant Investment in Canada: A Structural Model

Authors
Lin, C.-Y. Cynthia
Yi, Fujin

Publication Date
2012-09-01

Research Report – UCD-ITS-RR-12-19

Ethanol Plant Investment in Canada: A Structural Model

September 2012

C.-Y. Cynthia Lin
Fujin Yi

Institute of Transportation Studies ◦ University of California, Davis
One Shields Avenue ◦ Davis, California 95616
PHONE (530) 752-6548 ◦ FAX (530) 752-6572
www.its.ucdavis.edu

UCDAVIS
SUSTAINABLE TRANSPORTATION CENTER
of the Institute of Transportation Studies

Final Research Report S05-1

Ethanol plant investment in Canada: A structural model

September 2012

C.-Y. Cynthia Lin
Fujin Yi

Department of Agricultural and Resource Economics
University of California, Davis
One Shields Ave., Davis, CA 95616

Ethanol plant investment in Canada: A structural model[1]

C.-Y. Cynthia Lin and Fujin Yi

Most of the fuel ethanol plants in Canada were built recently and either use corn or wheat as feedstock. It is important to determine what factors affect decisions about when and where to invest in building new ethanol plants and which feedstock is chosen as feedstock. In this paper we model the decision to invest in ethanol plants using a structural model of a dynamic game. We find that 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.

Keywords: Canada, biofuels, investment, dynamic discrete choice model, structural model

JEL codes: Q16, Q42, L10

---

[1] Lin: University of California at Davis; cclin@primal.ucdavis.edu. Yi: University of California at Davis; yi@primal.ucdavis.edu. The research was supported by a grant from the Sustainable Transportation Center at the University of California at Davis, which receives funding from the U.S. Department of Transportation and Caltrans, the California Department of Transportation, through the University Transportation Centers program. Lin received financial support from the Giannini Foundation for Agricultural Economics. All errors are our own.

1. Introduction

There are several governmental policies in Canada designed to promote the development and use of renewable fuels such as ethanol. In May 2008, the Canadian government passed Bill C-33, which enabled it to establish a national renewable fuels mandate for the gasoline pool by 2010. A Notice of Intent in 2006 was published in the Canada Gazette Part I on December 30, 2006, which set an objective of mandating an average 5% renewable fuel content based on the gasoline volume. Based on the trend of net sales of gasoline used for road motor vehicles between 2005 and 2008, a federal mandate of 5% renewable fuel content would require a minimum production of 1.9 billion liters of fuel ethanol. The actual production of fuel ethanol in 2009, however, was only 1.348 billion liters (GAIN, 2010). Before that there have been several federal programs that promote a domestic renewable fuel industry, including the EcoEnergy for Biofuels Overview and the Agri-Opportunities Program. In addition, provincial incentive programs designed to encourage the development of a Canadian renewable fuels industry have also been introduced; for instance, Alberta, British Columbia, and Ontario provide an extra tax exemption for fuel ethanol production, and Saskatchewan and Manitoba set a higher blending mandate than the federal goal.

Canada's ethanol production capacity reached 1.135 billion liters by the end of 2008, a significant jump from the around 700 million liters production capacity in 2007 (GAIN, 2008). This surge in ethanol production suggests that the government support policies may have played a role in stimulating the development of fuel ethanol industry in Canada, although this has not been proven. A rigorous analysis of the effect of policy on ethanol investment should also control for the effects of other factors such as fuel ethanol prices, feedstock markets, incumbents' behavior, etc. Understanding the different effects of policy, economic and strategic factors on ethanol investment could help the government to design policies to develop this new industry in Canada.

Previous papers have attempted to address the decision of investing an ethanol plant in a static framework using U.S. data. Lambert et al. (2008) use a probit regression model along with spatial clustering methods to analyze investment activity of ethanol plants at the county level for the lower U.S. 48 states from 2000 to 2007. Five categories of factors determine the location of ethanol plant: infrastructure, product and input markets, fiscal attributes of local communities, and state and federal incentives. However, this analysis does not model the influence of existing ethanol plants on potential entrants.

Sarmiento and Wilson (2007) uses logistic regression with U.S. data to analyze the impacts from the agricultural characteristics of a county, competition, and state-level subsidies. The competition between existing ethanol plants and entrants are expressed by the distance. Their results conclude that existence of a competing ethanol plant reduces the likelihood of making a positive location decision and this impact decreases with distance.

The above empirical papers did not adequately capture the dynamic impacts of the factors that affect ethanol investment. Substantively, the dynamics may be more realistic and, hence, may provide a better description of behavior. More importantly, there may be patterns in the data that are simply not captured by a static model. Hence, ignoring the dynamics could potentially generate misleading conclusions about behavior (Dubé al., 2005). The two cross sectional models miss an important dimension of the investment decision: time. Investors not only choose whether to invest in ethanol plants but also choose when to enter the fuel ethanol industry. Their goal is to maximize the present discounted value of the entire stream of profits. Expectations about exogenous conditions such as factors affecting the input market and government policies will affect when and where ethanol plants will be built.

Schmit et al. (2010) consider the influence of policies on U.S. corn-based fuel ethanol investment decisions. A potential fuel ethanol investor's decision is determined by revenue and cost, two factors which are evolving over time with other covariates. According to the results, the current fuel ethanol industry expansion was induced by the revenue-enhancing effects of policy and, in the absence of these policies, much of the recent expansionary periods would have not existed. Due to limitations of their model, however, their study does not analyze the strategic interactions between ethanol plants. Schmit et al. (2010) allow the incumbents to exit if it is not profitable to produce fuel ethanol, however, due to the scarcity of exit observations for fuel ethanol plants in Canada, it is impossible to empirically recover the exit policy function. Our paper therefore focuses on the entry decision.

Lin and Thome (2010) use U.S. data to analyze which factors impact and how the incumbent ethanol plants influence the new entrants' investment decision under a dynamic framework. Their research indicates that availability of inputs is important in determining expected profits from investment in an ethanol plant and competition between plants is enough to deter local investment. However, the econometric model they used required them to discretize all the continuous state variables so that some important information may have been lost when the variables were binned. In addition, their model can only handle a binary investment decision, so cannot be used for analyzing the ethanol investment decision in Canada, where there are multiple feedstocks are available. In particular, Lin and Thome's (2010) analysis of the U.S. ethanol industry focused only on corn ethanol, since 95% of the ethanol in the U.S. is produced from corn, while our analysis of Canada examines both corn- and wheat-based ethanol plants.

Lin and Yi (2011) estimate a structural econometric model of the European fuel ethanol industry with 4 different feedstock choices: barley, corn, sugarbeet, and wheat. They found that fuel ethanol plants in Europe are so dependent on government support policies that several market factors such as ethanol prices are not significantly important. Lin and Yi (2011) assert that the investment of fuel ethanol plant should be analyzed in a dynamic game framework with the consideration of strategic decisions. They consider and define two different interaction effects: a *competition effect* and an *agglomeration effect*. The former effect arises when there are multiple ethanol plants located in one region if these plants compete in feedstock supply when they choose the same feedstock or compete in local fuel ethanol market given limited demand. The latter effect arises when there are several ethanol plants located in the same region if the local government invests in improving the infrastructure such as water supply, roads, etc. to support the ethanol industry development, or if there exists transportation and marketing infrastructure and educated work force developed by the existing plant. Lin and Yi (2011) emphasize that the competition effect usually deters ethanol plant investment, while the agglomeration effect induces an ethanol plant to locate near other plants. According to their results, the competition effect among European fuel ethanol plants outweighs the agglomeration effect.

This paper builds on the structural econometric models of Bajari et al. (2009) and Lin and Yi (2011). Based on the background of Canada fuel ethanol industry including the recent sharp increase and the interactions among plants, it is interesting to ask what factors recently affect the decision to invest in ethanol plants in Canada, and how ethanol plant location decisions are made. The estimation results are also able to show the differences between the European and Canadian fuel ethanol industries.

Our results show that fuel ethanol investment in Canada is quite different from the industry in Europe. First, government policy effects vary across fuel ethanol plants that are based on different feedstocks. Wheat-based plants are significantly affected by the policy, while the effect to plants using corn as feedstock is not obvious. Second, the interactions between potential entrants cannot be ignored in the Canadian fuel ethanol industry. If a potential entrant considers that there are many potential competitors, their investment might be deterred. However, these interactions are not significant in Europe.

The paper proceeds as followings. The structural econometric model of the dynamic game is described in Section 2. The results from the empirical estimation will be discussed in Section 3. Section 4 summarizes the main conclusions.

2. Structural model for ethanol plant investment

2.1 Dynamic game model

Structural models of dynamic games are useful tools 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.

The estimation of structural models of dynamic games are under the principle of revealed preference using individual's choices (Aguirregabiria and Mira, 2010). Recently, semi-parametric methods have been used to estimate structural parameters (Pesendorfer and Schmidt-Dengler, 2003; Pakes et al., 2007; Aguirregabiria and Mira, 2007). Bajari and Hong (2006), Bajari et al. (2007) and Bajari et al. (2009) added to this literature by proposing methods to estimate parameters in a dynamic game with continuous state variables.

Most of these econometric methods involve a two-step estimation procedure. The common logic is to use a specific equilibrium solution concept to work backward from the observed equilibrium action(s) to statements about unobserved profits (Reiss and Wolak, 2007). Research on dynamic competition has shown that computing an equilibrium for even relatively simple industry models is all but prohibitive (Bajari et al., 2007). The econometric method employed in this paper is based on the introduction of Hotz-Miller inversion (Hotz and Miller, 1993), and the estimations of equilibrium are simplified to two steps without analytically solving the equilibrium of a dynamic game, which reduces the high computational burden. In this two-step estimator, the economist first flexibly estimates the agent's policy functions, choice probabilities that are conditional on state variables and the other agents' actions, and the transition probabilities for state variables. Second, structural parameters from the period profit function are estimated.

Usually the first step is estimated using a nonparametric method based on discrete state variables. However, some state variables are naturally continuous. One could increase the number of grids in estimating the first stage choice probabilities to minimize the loss of information, but Bajari and Hong (2006) point out that the discretization has an offsetting effect: it increases the variance of the first step estimation. When the dimension of the continuous state variables is larger than four, it is not possible obtain $\sqrt{\mathrm{N}}$ consistent (where N is the sample size) and asymptotically normal estimators for the second stage parameters through discretization. Instead of discretizing continuous variables, Bajari and Hong (2006) and Bajari et al. (2009) suggest that policy and value functions can be approximated parametrically using a combination of basis functions in which the nonparametric first step estimation can be implemented using continuous state variables.

2.2 Theoretical model

Our model follows the model developed by Bajari et al. (2009) and used by Lin and Yi (2011). In the dynamic model of ethanol plant investment, each "market" m has I potential entrants. In the model, there are $t = 1, \cdots, \infty$ time periods. As in Aguirregabiria and Mira (2007), we assume that all the agents move simultaneously in each time period t and choose stategy a_{it} from the identical choice set $\{0,1, \cdots, K\}$, and that the random preference shocks are private information. Action $k = 0$ represents the outside option, which is to wait outside of the fuel ethanol market and not produce ethanol, and the rest of elements of numbers represent different feedstock choices available for fuel ethanol production.

The existence of multiple equilibria is a prevalent feature in most empirical games because the best response functions are nonlinear in other players' actions. Due to the difficulty of analytically solving for explicit multiple equilibria, we use the method suggested by Bresnahan and Reiss (1990, 1991). They consider a specification in which a firm's action depends on the number of firms that are operating in the market but not on the identity of these firms. Their assumption is that all the firms are symmetric and produce a homogeneous good. Then the number of equilibrium entrants is invariant over the multiple equilibria. Therefore, we will follow this method and use only the number of other plants choosing certain feedstocks, rather than the identity of the plants choosing certain feedstocks, to represent the strategic interactions.

An investor's time-t investment timing decision is assumed to be a function of the state of the market $\Omega_{mt} = (s_{mt}, a_{-it})$, a vector which include exogenous profit-shifting state variables s_{mt}, and the neighbor plants' actions a_{-it}. The Canadian Renewable Fuel Association reports that Canada had both first generation and second generation fuel ethanol producers by 2010. However, only 2 demonstration facilities out of 19 ethanol plants are producing ethanol using cellulosic biomass such as straw from wheat, barley and oats, and their capacities are extremely small. In 2010, it is estimated that 64% of the production of domestic fuel ethanol is derived from corn and 35% from wheat and 1% from "other" feedstock (GAIN, 2010). Therefore, our model only focuses on the first generation fuel ethanol plants using corn or wheat as feedstock. a_{-it} contains the number of existing and new ethanol plants in a given market which choose the same feedstock as the ethanol plant i, and the number of existing and new ethanol plants that choose different feedstocks. Owing to the competition and agglomeration effects, each investor's decision potentially depends on whether there are other plants nearby. As a consequence, each investor does not solve merely a single agent dynamic programming problem, but rather a multi-agent dynamic game.

The exogenous state variables s_{mt} includes *ethanol price, gasoline price, natural gas price, corn price, wheat price, corn production intensity, wheat production intensity, number of existing ethanol plants in local market*, and government ethanol support policies such as *financial incentives* and *blending mandates*. We assume that s is common knowledge to all players in the game and is observable to the econometrician. However, in order to identify the following model, we have to divide $s = (s_i, s_{-i})$ and s_{-i} are assumed *not* to enter into plant i's mean payoffs. For instance, a wheat-based ethanol plant is not affected by the corn price. All the above exogenous variables except policies are assumed to evolve according to a first-order Markov process $\bar{g}(s'|s, a_i, a_{-i})$, where s' are the next period exogenous state variables, and summarize the direct effect of the past on the current environment.

In addition to the publicly observed state variables Ω_{mt}, the expected profit from investing an ethanol plant depends on shocks that are private information to the ethanol plant but not observed by either other plants or by the econometrician. Let $\epsilon_{it} = (\epsilon_{it}(0), \cdots, \epsilon_{it}(K))$ denote a vector of $i.i.d$ shocks to potential plant i's payoffs at time t, and we assume the error terms are distributed extreme value and its density function is $f(\epsilon_{it}) = \exp(-\epsilon_{it})\exp(-\exp(-\epsilon_{it}))$

To reduce the notational complexity in the following sections, we drop the market subscript. Payoff in each time period depends on the agent's actions, the state variables and random preference shocks, and has the additively separable representation:

$$u_{it}(a_{it}, a_{-it}, s_t, \epsilon_{it}) = \Pi_i(a_{it}, a_{-it}, s_t) + \epsilon_{it}(a_{it}),$$

where the stochastic component is the privately observed shocks ϵ_{it} and the deterministic component of profit $\Pi_i(a_{it}, a_{-it}, s_t)$ is linear in the publicly observable state variables:

$$\Pi_i(a_{it}, a_{-it}, s_t) = s_t'\gamma_s + a_t'\gamma_a \quad .$$

Therefore, the development payoff is independent of time except through the state variables (s_t, a_t) and the shock ϵ_{it}.

Let $\gamma = (\gamma_s,\ \gamma_a)$ denote the vector of the coefficients in the investing fuel ethanol plant profit function. These are the parameters that we are going to estimate. The coefficients γ_s are for the publicly observed state variables such as ethanol prices, feedstock prices, etc. We expect that ethanol price, local feedstock production intensity and support policy would have positive effects on the ethanol plant payoff. For the current technology natural gas is an important bio-refinery heat source, so we expect the natural gas price to have a negative effect on the payoff. In the meantime, feedstock price would have negative impacts on the payoff. However, gasoline prices have ambiguous effects because an increase in the gasoline price could improve the demand of fuel ethanol as a substitute or increase the production cost of fuel ethanol, Similarly, the effect of number of existing ethanol plants is also uncertain, as the existing plants could compete in the limited feedstock market or share existing infrastructure and educated labor. The coefficients γ_a on the strategic variables thus measure the net effects of the agglomeration and competition effects, and therefore indicate whether ethanol plants interact strategically on net. Positive γ_a would indicate that the agglomeration and competition effects were positive on net, and therefore that the agglomeration effect is dominant. Negative values would indicate that the effects were negative on net, and therefore that the competition effect is dominant.

Lin and Yi (2011) not only define the competition and agglomeration effects between plants' interaction, they also argue that there are two different types of interactions based on different players: *incumbent interaction* and *entrant interaction*. Each potential entrant i not only observes the incumbent plants' action, but also knows the choice probabilities σ_{-i} of the other potential entrants. Then the decision maker i can interact with the existing plants, an interaction we call the *incumbent interaction*; and the decision maker i can also interact with other potential entrants given his belief about the others' choice probability σ_{-i}, an interaction we call the *entrant interaction*. Based on Lin and Yi's (2011) argument, we expect the magnitudes of the competition and agglomeration effects to be larger for existing incumbents rather than for new entrants that may enter at the same time. The reason is that the competition effect from incumbents is more negative because incumbents may have local market power (first-mover advantage), and the agglomeration effect from incumbents is more positive because the incumbent may have already established the infrastructure that a new plant can take advantage of. However, we cannot empirically distinguish these differences because our strategic variables only show the net effect of the competition effect and agglomeration effect.

Since each potential entrant has 3 strategies (stay out of fuel ethanol market, or either choose corn or wheat to produce fuel ethanol), the strategic variables are grouped by the strategy choices and the other plants' corresponding strategies. This setting is suggested by Bresnahan and Reiss (1990, 1991), which can avoid multiple equilibria. The signs of both strategic variables could be positive or negative. For instance, if fuel ethanol plant i chooses wheat as feedstock to produce fuel ethanol and the other new entrants also choose wheat, as mentioned above, then the sign is decided by the net effect of the competition effect and the agglomeration effect. If at least one of the other players chooses corn as its feedstock, then the sign of the strategic effect can still go either way. There may be less competition in the wheat feedstock market but the competition in the fuel ethanol market may still exist, especially when the fuel ethanol demand is not large enough at the developing phase of this industry in Canada. Moreover, the agglomeration effect in the ethanol market also exists although ethanol plants choose different feedstocks. In addition, insignificant signs for this group of strategic variables do not mean there is no interaction between two ethanol plants: it could result from the positive and negative effects exactly offsetting each other.

Let $\sigma_i(a_i|s)$ denote the probability that fuel ethanol plant i choose action a_i given state variable s, and $W_i(s, \epsilon_i; \sigma_{-i})$ is the fuel ethanol plant i's value function given state s, private information ϵ_i and holds fixed the strategies of the other plants σ_{-i}. In a Markov perfect equilibrium, the ethanol plant investor's strategy $a_i(s, \epsilon_i)$ and corresponding conditional choice probabilities $\sigma_i(a_i|s)$ are solving the following maximizing value function:

$$W_i(s, \epsilon_i; \sigma_{-i}) =$$
$$\max_{a_i}\{\Pi_i(a_i, s; \sigma_{-i}) + \epsilon_i(a_i) +$$
$$\beta \int \sum_{a_{-i}} W_i(s', \epsilon_i'; \sigma_{-i})\ \bar{g}(s'|s, a_i, a_{-i})\sigma_{-i}(a_{-i}|s) f(\epsilon_i') d\epsilon_i' ds' \}$$

where the term $\Pi_i(a_i, s) + \epsilon_i(a_i)$ is the current period payoff if the plant chooses a_i. The rest part captures the discounted future utility, and it integrates over ϵ_i' and s', where the ethanol plant investor has to take into account the next period shock ϵ_i' and observed state variables s'. For the structural estimation, we set the discount factor β to 0.9.

Then, we can define a choice specific value function $V_i(a_i, s)$ as

$$V_i(a_i, s) =$$
$$\Pi_i(a_i, s; \sigma_{-i}) + \beta \int \sum_{a_{-i}} W_i(s', \epsilon_i'; \sigma_{-i})\ \bar{g}(s'|s, a_i, a_{-i})\sigma_{-i}(a_{-i}|s) f(\epsilon_i') d\epsilon_i' ds'$$

which is interpreted as the returns excluding $\epsilon_i(a_i)$ when the ethanol plant chooses current strategy a_i and all the future period strategies and payoffs adjust. Then, we can define the *ex ante* value function as:

$$V_i(s) = \int W_i(s, \epsilon_i; \sigma_{-i}) f(\epsilon_i) d\epsilon_i.$$

The *ex ante* value function is the expected value of W_i in the future given that current state is s. Therefore, we can rewrite the choice specific value function through the following equation:

$$V_i(a_i, s) = \Pi_i(a_i, s) + \beta E[V_i(s')|s, a_i].$$

At last, we can derive the equilibrium probabilities using the choice specific value function using the following equation:

$$\sigma_i(a_i|s) = \frac{\exp(V_i(a_i,\ s))}{\sum_{a_i'} \exp(V_i(a_i',\ s))}.$$

2. 3 Econometric estimation

Our goal is to use the Canadian data to estimate the mean utility parameters $\hat{\gamma}$ in $\Pi_i(a_i, a_{-i}, s)$. The econometric estimation technique we use follows the method developed by Bajari et al. (2009) and applied by Lin and Yi (2011). First, we estimate the choice probabilities $\hat{\sigma}_i(k|s)$ flexibly using a sieve logit, where the sieve logit estimator is simply the standard multinomial logit where the covariates are selected basis functions, and a sieve of polynomial spaces are selected. The estimation is based on pooled data from all the markets, therefore we have to assume that the data are generated by a single Markov perfect equilibrium profile **σ** which is a stronger assumption (Bajari et al., 2007). Second, we apply the Hotz-Miller inversion to compute $\hat{V}_i(k,s) - \hat{V}_i(0,s)$. Then, we can estimate $\widehat{\Pi}_i(a_i, s_{mt})$, the static choice specific value function given that the action is a_i and the state is s_{mt}. All these estimation steps are nonparametric and do not impose *ad hoc* functional form restrictions. Fourth, semiparametric estimators $\hat{\gamma}$ are the solutions to the following minimization problem:

$$\hat{\gamma}_{i,a} = \text{argmin}_{\Pi_i(a_i,a_{-i},s_i)} \sum_{m=1}^{M} \sum_{t=1}^{T} \widehat{\Pi}_i(a_i, s_{mt}) - \sum_{a_{-i}} \hat{\sigma}_{-i}(a_{-i}|s_{mt})\, \Omega'_{mt} \gamma_{i,a}\,.$$

As the common result in semiparametric estimation, $\hat{\gamma}$ converges to the true value at a rate proportational to the square root of the sample size and has a normal asymptotic distribution (Bajari et al., 2009).

Standard errors are formed by a nonparametric bootstrap. Markets are randomly drawn from the data set with replacement to generate 100 independent panels of size equal to the actual sample size. The structural econometric model is run on each of the new panels. The standard error is then formed by taking the standard deviation of the estimates from each of the random samples.

3. Data and results

3.1 Data

Canada has 10 provinces and 3 territories. The 3 territories are not appropriate for agricultural production due to their extreme climate. Hence, we only use data from the 10 provinces. Each province is divided into several Census Agricultural Regions (CAR) and each of them is assumed to be a separate market. We assume that in each market there are 3 potential fuel ethanol plants that may potentially enter the market. Table 1 shows the average area for the CAR for every province.

The panel spans the years 2001 to 2007. There are 12 ethanol plants in total in Canada, of which 5 fuel ethanol plants were built before 2001. The earliest plant started to produce ethanol in 1981 and is located in Manitoba province. Of the 12 plants, 5 ethanol plants use corn as a feedstock and 7 plants use wheat. Therefore, the ethanol plants have three strategies, i.e., $a_i \in \{\text{outside option, corn, wheat}\}$.

Table 1. Ethanol plants description

Province	Number of markets	Number of ethanol plants	Average area for each market(km^2)
Alberta	8	1(1)	80006
Ontario	5	4(2)	179033
Manitoba	12	2(1)	46031
Quebec	14	1	94277
Saskatchewan	20	4(1)	29414
British Columbia	8	0	120639
New Brunswick	4	0	17690
Prince Edward Is	3	0	1895
Newfoundland	3	0	123498
Nova Scotia	5	0	10583
Total	82	12(5)	23064

Note: Number of ethanol plants built before 2001 is in parentheses.

The state variables were chosen based on considerations of state space and data availability. In this study, our estimation does not rely on the discreteness of the state space which is particular achieved by using an estimation approach that does not need preliminary estimation of the continuation values of the players (Bajari et al., 2009), i.e., we can keep the continuous state variable as they are.

Table 2. Summary Statistics

Variable	Mean	Standard Deviation	Min	Max
Ethanol Price ($/ton)	720.000	63.975	640.000	850.000
Natural Gas Price (¢/m^3)	27.676	7.244	8.590	44.860
Gasoline Price ($/liter)	0.868	0.117	0.665	1.053
Corn Price ($/ton)	117.734	22.895	90.010	184.810
Wheat Price ($/ton)	128.087	39.471	67.277	253.440
Corn Intensity (000ton/km^2)	0.007	0.027	0	0.229
Wheat Intensity (000ton/km^2)	0.014	0.018	0	0.077
Cattle Density (head/km^2)	8.990	9.326	0.015	45.651
Hog Density (head/km^2)	14.015	28.378	0.007	164.476
Chicken Density (000head/km^2)	0.433	0.912	0.000	4.598
Financial Support*	0.120	0.325	0	1
Blending Mandate*	0.078	0.269	0	1

Notes: * represents binary variables

The first exogenous state variable is the ethanol price for every market m at time t, however, the ethanol prices are not available for each specific region. For this reason, we have to assume that regional ethanol price is equal to the national price. According to the United Nations Statistics Division (UNSD) data, Canada is a net fuel ethanol importer, hence we are using the import ethanol price from the Global Information, Inc.

The second state variable is the natural gas price. We are using provincial industrial natural gas prices from the Statistics Canada (SC), and each CAR's natural gas price is equal to the provincial price.

The third state variable is the gasoline price. Gasoline prices are not available either for each agricultural region or for each province. However, SC provides yearly wholesale prices for selected cities. To determine the province-level gasoline prices we compute the average gasoline prices over all the cities in one province and use it to represent the provincial prices. For each province for which there are no city prices available, we use national gasoline prices for all the agricultural regions in the province.

The fourth type of state variable is feedstock information. Two sets of agricultural information for census agricultural regions are available from the corresponding provincial government including production intensities and livestock densities. In the meantime we have to set CAR corn and wheat prices equal to corresponding provincial prices if they are available. However, several provinces do not produce wheat or corn such as Prince Edward Island and Newfoundland, and we set those provincial feedstock prices equal to national prices.

The fifth type of state variable is support policies of government, which are from Canada Bio-fuel annual report (GAIN, 2008). There are 2 different types of support policies: financial support policies including tax exemption and incentive programs, and blending mandates. The most common policy, a direct subsidy, is not included because the federal payment starts from 2008 but our panel ends in 2007. Financial support includes the tax credit and direct funding support from local government. Blending quota represents the exact percentage mandate that the gasoline should contain ethanol. All these policies are shown in table 3 and vary across the provinces. In addition, some provinces such as Saskatchewan have gone forward and implemented provincial mandates on the amount of ethanol required in the gasoline pool before the federal government committed to a mandate. Hence, the starting dates of the support or mandate are designated as the earliest time between federal and provincial policies.

Table 3. Current Bioethanol Standards by Province

Province	Percentage of Ethanol Mandate	Tax Exemption or Incentive Program Duration
Alberta	5%*	2007-2011
British Columbia	5%	2010-
Saskatchewan	7.5%	2008-2012
Manitoba	8.5%	2010-2012
Ontario	5%	2007-2017
Quebec	5%**	2006-2018
New Brunswick	5%***	-

Notes: (1) Data are from GAIN report, 2010. (2)*Target by 2011; ** Target by 2012; ***Co-operation with federal government

3.2 Results

In the estimation, we have three groups of covariates: the constant term for plant i's action; interactions between state variables and specific choice variables; and strategic variables. Due to the 3 strategies (outside option, either chooses corn or wheat to produce fuel ethanol), the strategic variables are grouped by the strategy choices and the other plants' corresponding strategies: the number of the other plants who choose the same strategy as i or not.

Table 4. Estimation results of profit function

	Explanatory Variables	Corn		Wheat	
		Coefficients	Standard error	Coefficients	Standard error
Constant	Constant	-728.44***	71.40	22.37	54.57
State variables	Ethanol price	96.35	56.64	142.68***	43.17
	Natural gas price	-581.48***	28.04	-1115.02***	13.07
	Gasoline price	111.89	72.51	462.75***	54.27
	Feedstock price	-454.30***	11.21	-838.51***	9.33
	Feedstock intensity	1153.87***	1.25	876.80***	0.55
	Cattle density	191.61***	5.03	-728.09***	4.78
	Hog density	-3.13**	1.47	-197.94***	1.44
	Chicken density	74.39***	2.11	73.10***	0.15
	Financial support	40.94	47.16	93.85**	32.82
	Blending quota	39.94	32.28	161.35***	22.23
Strategic variables	# ethanol plants that already exist using the same feedstock	812.15***	12.29	-287.32***	11.76
	# ethanol plants that already exist using the different feedstock	-80.00***	17.12	-100.00***	21.36
	# of new plants choosing same feedstock this year	-648.24***	32.75	-226.97***	22.34
	# of new plants choosing different feedstock this year	-192.71***	28.83	-106.67***	25.39

Notes: Standard errors in parentness. Significance code: *5% level, **1% level, ***0.1% level.

Table 4 presents the model results. All the covariates have expected signs. The ethanol price does have positive effect on the fuel ethanol plant's profit although it is not significant for the corn-based fuel ethanol plant. As an input, natural gas has a negative effect on the profit that is significant at 0.1% level for both corn and wheat ethanol plants. Gasoline price has a significant positive effect on wheat-based fuel ethanol plants but does not have a significant effect on corn-based plants. This suggests that for wheat-based plants, the positive effect of gasoline price on profits due to the complementary nature of gasoline and ethanol when blended in fuel outweighs the negative effect of gasoline price on profits due to its use as an input.

Feedstock costs are the largest component of the cost of ethanol production. As expected, region-level feedstock price and feedstock production intensity have significant negative and positive effects on the profit, respectively. All of them are significant at 0.1% level.

There are interesting results governing the relationships between ethanol plants and livestocks. For corn-based fuel ethanol plants Table 4 shows that hogs compete with ethanol plants in the feedstock market and the competition effects dominate the positive effect that the waste product can feed hogs, while the effects from the density of cattle and chicken have opposite affects. The competition effect dominates for cattle and hog for wheat-based plants.

As expected, all policies have positive effects on ethanol plant profits although they are not significant for corn-based plants.

The interaction effects from incumbents are different from those from new entrants. The existence of incumbents lowers the profits for wheat-based plants. In the meantime, corn-based plants benefit if the incumbent plants also choose corn but their profits are lower if the incumbents choose wheat. These results are a little unexpected, however, it is still interpretable from the infrastructure and labor education: the new entrant could free ride off the infrastructure and human capital investments of the incumbents if the incumbents are using the same production technology. On the other hand, the effects of other potential entrant plants' choices have significant negative effects on plant i's profit. If plant i chooses corn and wheat, then, regardless of which feedstock will be chosen by the other potential entrants, potential entrants would always harm potential plant i's profit.

4. Conclusion

This paper constructs a dynamic game model for Canadian fuel ethanol plants that incorporates the effects of interactions between two fuel ethanol plants' investment decisions in the same local market. Structural parameters measuring the effect of profit shifters are estimated semi-parametrically.

According to our results, a potential investor considers various exogenous conditions: higher ethanol prices, gasoline prices and plenty of feedstocks increase profits, typically for wheat-based plants, while a high natural gas price and feedstock prices decrease profits. Government support helps improve wheat-based ethanol plant's profit but does not have significant effects on corn-based plants. Livestock effects differ based on feedstock choices. The corn- or wheat-based fuel ethanol plant operator should consider the net negative effect which arises when the other plants also plan to use corn or wheat as well. The net negative effect of strategic interactions may partially offset the positive effects of government financial support policies.

Obtaining local fuel ethanol price is the subject of ongoing research, and we hope in future work to incorporate the local data into our analysis. Our use of national rather than local price data may explain why some fuel ethanol price and gasoline price variables are not significant.

References

Aguirregabiria, V., and Mira, P. (2007). "Sequential Estimation of Dynamic Discrete Games". *Econometrica*, 75(1):1–53.

Aguirregabiria, V., and Mira, P. (2010). "Dynamic discrete choice structural models: A survey," *Journal of Econometrics*. 156(1):38-67.

Bajari, P., Benkard, C., and Levin, J. (2007). "Estimating Dynamic Models of Imperfect Competition". *Econometrica*, 75(5):1331-1370.

Bajari, P. and Chernozhukov, V. and Hong, H. and Nekipelov, D.(2009). "Nonparametric and Semiparametric Analysis of a Dynamic Discrete Game." Manuscript, University of Minnesota.

Bajari, P. and Hong, H. (2006). “Semiparametric Estimation of a Dynamic Game of Incomplete Information.” NBER Technical Working Paper, No. T0320.

Bresnahan, T., and Reiss, P. (1990): “Entry in MonopolyMarkets,” *Review of Economic Studies*, 57(4): 531–553.

Bresnahan, T., and Reiss, P. (1991): “Empirical Models of Discrete Games,” *Journal of Econometrics*, 48(1-2):57–81.

Dubé, JP, Sudhir, K., Ching, A., Chawford,G. S., Draganska, M., Fox, J., Hartmann,W., Hitsch, G. J., Viard, V. B., Villas-Boas, M. and Vilcassim, N. (2005). “Recent Advances in Structural Econometric Modeling: Dynamics, Product Positioning and Entry,” *Marketing Letters*, 16(3/4):209-224.

Global Agricultural Information Network (GAIN) (2008):“Canada Biofuels Annual Report”. USDA Foreign Agricultural Service, GAIN Report Number: CA8057.

Global Agricultural Information Network (GAIN) (2010):“Canada Biofuels Annual Report”. USDA Foreign Agricultural Service, GAIN Report Number: CA0023.

Kenkel, P., and Holcomb, R.B. (2006). ‘‘Challenges to Producer Ownership of Ethanol and Biodiesel Production Facilities.’’ *Journal of Agricultural and Applied Economics*, 38,(2):369–375.

Lambert, D. M., Wilcox, M., English, A., Stewart, L. (2008). “Ethanol Plant Location Determinants and County Comparative Advantage”. *Journal of Agricultural and Applied Economics*, 40:117-135.

Lin, C.-Y.C. and Thome, K. (2010). “Investment in Corn-Ethanol Plants in the Midwestern United States”. Working paper, University of California, Davis.

Lin, C.-Y.C. and Yi, F. (2011). “What Factors Affect the Decision to Invest in a Fuel Ethanol Plant? A Structural Model of the Investment Timing Game in Europe.” Working paper, University of California, Davis.

Pakes, A., Ostrovsky, M. and Berry, S. (2007): “Simple estimators for the parameters of discrete dynamic games (with entry/exit examples)”. *Rand Journal of Economics*, 38(2):373-399.

Pesendorfer, M., and Schmidt-Dengler, P. (2003): “Identification and Estimation of Dynamic Games,” Working Paper 9726, NBER.

Reiss, P.C. and Wolak, F.A. (2007), “Structural Econometric Modeling: Rationales and Examples from Industrial Organization,” *Handbook of Econometrics*, Volume 6A, (edited by James J. Heckman and Edward E. Leamer), 6:4277-4415.

Sarmiento, C., and Wilson, W. (2008). “Spatial Competition and Ethanol Plant Location Decisions,” 2008 Annual Meeting, July 27-29, 2008, Orlando, Florida 6175, American Agricultural Economics Association.

Schmit, T., Luo, J., and Conrad, J. (2010), “Estimating the Influence of Ethanol Policy on Plant Investment Decisions: A Real Options Analysis with Two Stochastic Variables.” Working paper, Cornell University.