A Structural Estimation of the Demand for Corn Seed in the US

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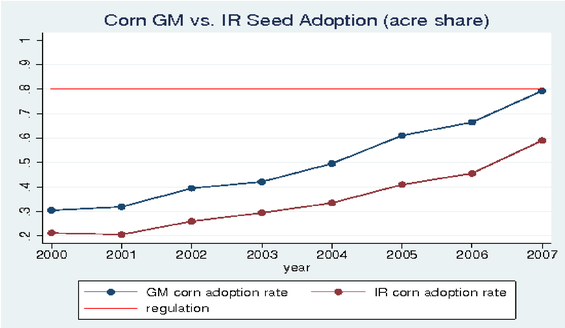
Poster prepared for presentation at the Agricultural & Applied Economics Association's 2010 AAEA, CAES & WAEA Joint Annual Meeting, Denver, Colorado, July 25-27, 2010.

Research Question

Genetically Modified(GM) seed has been rapidly adopted in recent years, but the social welfare effect of this new technology is still unclear for us. Motivated by clear economic meaning, structural approach allows for behavior model test and social welfare effect assessment. The purpose of this paper is to use the newly developed structural estimation models and techniques to estimate farmers' demand for GM seed and to evaluate the social welfare of introduction of new seed technology.

Background

Fast GM Corn Seed Adoption:



Logit Model

Suppose for j^{th} type of corn hybrid, x_j is a vector of characteristics and ξ_j is the unobserved characteristics. With price p_j, the profit for farmer i to grow seed j is

$$\pi_{ij} = \beta x_j - \alpha p_j + \xi_j + \varepsilon_{ij}. \tag{1}$$

where ε_{ij} is an i.i.d. error with extreme value distribution. Normalize the price of the outside option as zero, and let $\delta_j = \beta x_j - \alpha p_j + \xi_j - \xi_0$, then

$$\pi_{ij} = \delta_j + \varepsilon_{ij} \quad \text{for } j = 0, 1, 2, \ldots, J. \tag{2}$$

According to the Logit model, the probability s_j that the farmer will choose j^{th} type of corn seed is

$$s_j = \frac{e^{\delta_j}}{1 + \sum_{l=1}^{J} e^{\delta_l}} \quad \text{and} \quad s_0 = \frac{1}{1 + \sum_{l=1}^{J} e^{\delta_l}}$$

which is virtually the market share of seed j. Follow the standard approach we can derive

$$logs_j - logs_0 = \beta x_j - \alpha(p_j - p_0) + (\xi_j - \xi_0). \tag{3}$$

Assuming the unobserved attribute ξ is independent with prices and observed characteristics, we can estimate β and α in Equation (3) using ordinary least square (OLS) estimation.

BLP model

BLP model assumes heterogeneous consumers, i.e., farmers have different reactions to each trait of the seed. So

$$\beta_i = \bar{\beta} + \Pi D_i + \Sigma \nu_i, \qquad \nu_i \sim N(0, 1)$$

where D_i is a vector of demographic variables of farmer i, ν_i is a vector of her unobserved tastes for each product characteristics. Then

$$\pi_{ij} = x_j \bar{\beta} - \alpha p_j + \xi_j + \Pi D_i x_j + \Sigma \nu_i x_j + \varepsilon_{ij},$$

Let $\delta_j = x_j \bar{\beta} - \alpha p_j + \xi_j - \xi_0$ defined as the mean profit derived from seed j, and $\mu_{ij} = \Pi D_i x_j + \Sigma \nu_i x_j$ defined as the farmer's specific heterogeneous taste for attributes in seed j, then

$$\pi_{ij} = \delta_j + \mu_{ij} + \varepsilon_{ij}. \tag{4}$$

Similar as in the Logit model, the probability of farmer i choosing seed j, P_{ij}, is

$$P_{ij} = \frac{e^{\delta_j + \mu_{ij}}}{1 + \sum_{l=1}^{J} e^{\delta_l + \mu_{il}}}$$

Suppose ν and D follow some distribution $F(\nu, D)$, then the market share can be obtained by integrated P_{ij} over all ν_i and D_i,

$$s_j = \int P_{ij} \mathrm{d}F(\nu, D). \tag{5}$$

BLP provided a contraction mapping to get the mean profit vector δ:

$$T(\delta) = \delta + ln(s^n) - ln(s) \tag{6}$$

Recall that

$$\delta_j = x_j \bar{\beta} - \alpha p_j + \xi_j - \xi_0 \qquad \text{for } j = 1, 2, \ldots, J. \tag{7}$$

Suppose Z is a set of instrument variables which are independent of ξ. Let $g = Z \cdot \xi$, then we can estimate the parameters in (7) by minimizing the GMM objective function

$$\min_{\alpha, \bar{\beta}} g' W g$$

where W is a $M \times M$ weigh matrix.

Data and Result

Data:

We use the data from an extensive survey on U.S. corn farmers in 2007. It provides information including farmers' purchasing records like prices, discounts, quantities, acreage, etc, and information about the seed itself, like seed variety, embedded biotech traits, brand, etc. This survey also provides a projection factor to aggregate the farmer level information to market level statistics. There are a total of 25,588 purchase records with 5,714 surveyed farmers from 34 U.S. states in our data set. The market is defined as the state level.

The characteristics of the hybrids include insect resistance which can kill the European Corn Borer(ECB) or root worms(RW), and herbicide tolerance(HT) which is designed to reduce weeds. A typical GM corn seed may contain one or more traits from the same bio-tech company or different bio-tech companies. The following table shows the stacking of corn seed. Among the stacked seed, BtHT and BtRWHT are the dominant stacking seeds, so we take these two stacking system as additional characteristics in the following estimation.

Conv	Single Bt	Single RW	Single HT	BtRW	BtHT	RWHT	BtRWHT	total
2820	1064	94	2559	299	3605	382	2240	13063

Result:

variables	logit		logit IV		BLP without IV		BLP IV	
	coeff	se	coeff	se	coeff	se	coeff	se
Constant	-0.751	0.051	3.464	0.747	1.052	0.058	0.337	0.642
Bt	-0.324	0.066	1.475	0.335	-1.784	0.078	1.024	0.286
RW	-0.442	0.084	1.542	0.381	-1.537	0.201	3.790	0.337
HT	-0.269	0.053	1.440	0.334	-0.927	0.062	2.802	0.283
BtHT	0.493	0.085	-0.271	0.194	2.859	0.090	-2.201	0.165
BtRWHT	0.583	0.107	-0.678	0.283	5.293	0.224	-2.458	0.257
price	0.025	0.001	-0.065	0.017	-0.0047	0.001	-0.0048	0.014

Instrument Variables:
Instrument variables are the brand of traits embedded in the seed. Because the Seed company has to pay license fee in order to get the right to use the trait, and the brands of those traits are proxies of the quality, therefore the brand of traits contain the cost information of those traits. From the preliminary results in the above tables we can see that after introducing the instrument variable, the coefficient for price changed changed from positive to negative in the logit case and increased in multitude in the BLP model. All the other coefficients are also consistent with our expectation.

Social Welfare Implication: TO DO

Reference

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