COMPANY PARTICIPATION IN SOYBEAN VARIETY TESTING PROGRAMS IN ILLINOIS

BY

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THESIS

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Abstract

This thesis analyzes location characteristics that affect companies' selection of testing regions in variety trials in Illinois. Agricultural R&D from the private sector has surpassed the public sector as the main source of soybean varieties since the 1990s. Private participation of the variety testing programs forms a vital part of the service of providing public information and introducing new varieties. Using data from University of Illinois and Farmers' Independent Research of Seed Technologies from 2000 to 2015, I find that when controlled for varieties' maturity groups, regional characteristics exhibit limited influence over the selection process. One significant factor is locations' market potential, approximated by the proportion of planting acreage, which inversely affects the likelihood of a location being selected before the entrance of FIRST in 2008.

To mom and dad.

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1

Introduction

As an important step in the development of crop varieties, variety testing programs provide yield information of new soybean varieties before their market launch. Independent variety testing programs provide objective reference points to compare the performance of varieties. In the US, the Cooperative Extension System has been the established provider of the service. Companies participate in these programs to demonstrate the performance of their seeds against that of competing firms. The results of variety trials are made available to farmers through various channels. The performance metrics from variety trials help farmers compare products and make more informed purchase decisions. In this regard, the information provided by the program serves as a public good to mitigate information asymmetry between seed companies and farmers. The value of variety testing programs lies in the value of the public information about the performance metrics of new varieties. Companies recognize the value of this public good by paying a fee to participate in the programs. Lee and Moschini (2022) have shown that farmers are willing to pay a higher price for novel varieties tested by variety testing programs.

In the U.S., while funding for public agricultural research has stagnated, the private sector has assumed a more prominent role in agricultural R&D. Key components of the public agricultural research were formed in the early 1900s through the establishment of land-grant universities, state experiment stations and extension systems. Public R&D played a dominant role in agricultural research in the 19th and most of the 20th century (K. Fuglie et al., 2011). In recent decades, however, funding for agricultural R&D in the public sector has declined in real terms (Clancy, K. Fuglie, et al., 2016). At the same time, the private sector has increased R&D spending dramatically as a result of intellectual property protection of biological innovations and advancements in biotechnology such as genetic engineering (Heisey et al., 2001). Public R&D programs are seeking ways to leverage and collaborate with private research (K. O. Fuglie and Toole, 2014).

Given this context, I investigate the participation in variety testing programs in Illinois. In variety trials, location choices offer a unique angle to understand the decision-making process of companies. Specifically, I ask: how do companies select locations in variety trials? What are the characteristics that make one region more attractive than another? In soybean production, farmers use varieties' traits such as maturity groups to select varieties best suitable for the plot (Nafziger, 2009). Location selection based on varieties traits is expected to be the established convention and part of the standard procedure. While I take into consideration the effect of variety-level traits, I investigate the effect of regional characteristics such as weather, regional yield and market potential.

This study focuses on two variety testing programs in Illinois. The University of Illinois (UIUC) has been running a state-wide variety testing service since 1934 (Joos, 2021). Farmers' Independent Research of Seed Technologies (FIRST) is an independent provider of corn and soybean seeds trials founded in 1997 (FIRST, n.d.). Testing sites of FIRST range across the corn belt and mid-Atlantic regions. The variety trials from the two programs provide traits and yield information of individual varieties.

I use the conditional logit model to establish the choice scenario of companies choosing test regions for each variable between 2000 and 2015. I show that market potential of choice regions, approximated by proportion of soybean planting area, is a significant factor in location decisions between 2000 and 2008, independent of varieties' maturity groups. There is a inverse relationship between the proportion of soybean planting area and the likelihood of a location been selected. This suggests that companies are willing to test varieties at locations with a smaller share of soybeans production where there is potential for expanding production. Other regional characteristics such as weather and past yield have little effect over the location decisions.

This study is the first to analyze company participation in variety testing programs. As private R&D in agriculture continues to grow, extension services such as variety testing programs are uniquely positioned to engage with private companies to provide public information. Most existing literature on extension programs focuses on estimating the productivity growth and economic benefits of the extension programs (Dinar et al., 2007; Jin and Huffman, 2016; Lee and Moschini, 2022). The present study complements the literature on the extension service through an analysis of the private sector's participation and decision-making process. Understanding how companies select locations for variety trials not only allows us to better grasp the performance results of the trials, but also guides how public sector can better engage with the private R&D.

The remainder of this article is organized into four sections. Section 2 presents the background information about the dynamic of private and public agricultural research and the seed industry. Section 3 describes the variety testing data and the condigitonal logit model for location decisions. Section 4 describes the estimation results. Section 5 concludes.

2

Background and Related Work

The variety testing program is positioned at the intersection of the public and private R&D institutions. Historically, the public sector has played a dominant role in agricultural research. Most of the agricultural research took place in the public research institutions such as land-grant universities and state experiment stations. As an integral part of the public R&D, the extension system was established to offer education programs at the local level and disseminate new practices from experiment stations' research. In the past two decades, the extension system has experienced a decline in funding and personnel. At the same time, the private sector has increased its R&D investment significantly. The introduction of patented genetically modified varieties has profoundly shaped the agricultural landscape and consolidated the industry. The variety testing program serves as an important information provider between the farming community and the private sector. In this section, I provide background information on the public and private agricultural R&D, the extension system and the seeds industry. Then I present hypotheses on companies' location choices, which will subsequently guide my methodological choices.

2.1 Agricultural Research in the Public Sector and The State of the Cooperative Extension System

Landmark U.S. farm bills in the late 19th century established key components of the public sector's agricultural research and extension. The Morrill Acts of 1862 created land-grant universities to educate citizens in agriculture, home economics and other practical professions. Subsequently, the Hatch Act of 1887 established state experiment stations at land-grant universities to strengthen agricultural research and education. The state experiment stations are credited with improving agricultural productivity through the introduction of new crop varieties and commercial fertilizer, among other innovations. Kantor and Whalley (2019) have documented the significant productivity growth at counties close to experiment stations after their establishment in the late 19th century and the subsequent diffusion of crop innovations. The extension system, formally known as the Cooperative Extension System (CES), was established in 1914 by the Smith-Lever Act through the partnership of USDA and land-grant universities to apply research from land-grant universities and experiment stations in agriculture. Today, the state experiment stations and CES are operated through land-grant universities in partnership with the federal, state and local governments.

The extension system has played an important role in the dissemination of new technologies. In the post-war period, productivity growth has been the primary driver of growth in agricultural production. Between 1948 and 2011, the total U.S. agricultural production was 2.5 times its 1948 level, while the inputs only grew by 4% (Wang, 2014). Studies have shown that extension plays a key role in adopting new technologies (Birkhaeuser et al., 1991). In a recent study focusing on a similar extension program in Iowa, Lee and Moschini (2022) have shown that the information from variety trials increased the willingness to pay for the soybean cyst nematode (SCN) resistant varieties. Using variety level soybean seed purchase data and variety trials data from Iowa State University, Lee and Moschini use a nested logit model to show that farmers' WTP for top-performed, university-tested SCN resistant varieties is higher than SCN varieties not tested by the program by $7/acre.

As modes of production have shifted significantly in the past few decades, so has the role of the extension programs. Farm operations in the U.S. have become more concentrated and specialized. The midpoint acreage for the U.S. cropland nearly doubled between 1982 and 2007. The increase in farm size is accompanied by higher levels of specialization, a process where livestock farming is separated from crop farming (MacDonald et al., 2013). At the same time, farmers are more reliant on retailers and crop advisors for production advice (Samy et al., 2003). There is evidence that the role of extension as an information provider has been sidelined by the private sector over time. In the 1960s, survey data from the Midwestern farmers showed that while agribusiness plays a greater role in farmers' decision making related to new technologies and prices, extension is ranked as the most important source of production information (Mawby and Haver, 1961). Schnitkey et al. (1992) surveyed commercial farmers in Ohio in 1987 and concluded that the extension system is ranked highly as an information source, especially with regard to general information as opposed to product-specific information, where salespeople excel. In a more recent study, Prokopy et al. (2015) suggest that the extension has a limited influence on U.S. medium- to large-sized corn producers' agricultural practices and strategies compared to family, chemical dealers, seed dealers and crop advisors. They find that a combined 40% of farmers reported that they have no contact with extension or extension has no influence on their decision-making processes. At the same time, the extension system is also experiencing significant transformations. The total extension spending in constant dollars has declined since the 1980s. Extension programs have increasingly relied on State and local funding. The number of full-time-equivalent (FTE) staff has also declined between 1980 and 2010, though the change is unevenly distributed across regions, with the Southeast region (including South Carolina, Alabama, Georgia and Florida) experiencing a substantial 45% decline in total FTE (Wang, 2014).

2.2 Private R&D Investment And the Consolidation of the Seed Industry

Since the late 20th century, plant breeding in agriculture has become increasingly privatized. Farmers use crop seeds from three sources: farmer-sourced or saved seeds, commercial seeds developed by the public sector and commercial seeds from the private sector. Seed-saving had been a widespread practice for soybean growers in the U.S. for much of the 20th century (Mascarenhas and Busch, 2006). Innovations of new varieties often come from public and private sector R&D programs, which involve substantial investment. The public breeding program has been a major source of new crop varieties. In the U.S., the public and private-sector research serve different but complementary roles, where the public sector tends to focus on upstream, fundamental science, while the private sector focuses on applied research and technology development (K. O. Fuglie and Toole, 2014). In the second half of the 20th century, private sector investment in plant breeding grew rapidly, surpassing public expenditures by a considerable margin by the 1990s. At the same time, more and more farmers are adopting private varieties. Heisey et al. (2001) report that in the United States, the share of areas planted to public varieties compared to private varieties declined drastically from 1980s to 1990s. This trend is particularly salient for soybeans, where in 1980, only 8 percent of the land used private varieties, but in 1997, this figure grew to 70-90 percent.

The introduction of genetically modified crops has significantly transformed the seed industry. The distinguishing feature of GM crops is the insertion of foreign genes to the plant's genome. In corn and soybeans, these traits fall into two categories: herbicide tolerance and insect resistance. Most herbicide-tolerant crops are tolerant to glyphosate, a broad spectrum of herbicides marketed by Monsanto under the trademark Roundup. With large-scale breeding programs that develop new, often stacked GM varieties through exclusive genetics, a few multinational seed companies have since dominated the seed market. The progress in genetic engineering has bought about three complementary markets: the traditional market for improved germplasm (or seed), the market for genes that confer desirable traits and the market for platform technologies or tools (K. Fuglie et al., 2011). Since the 1970s, much of the merger and acquisition in the seed industry has centered around access to intellectual property rights. Another feature of the present-day seed industry is the close overlap of seed and agricultural chemicals industries.

The introduction of GM crops is inseparable from the formal protection of intellectual property rights (IPR) in agriculture. Protection for intellectual property rights in plant breeding provides incentives for biological innovations in the seed industry. Traditionally, scientific discoveries, including biological innovations, are typically excluded from patents. An important measure to protect breeders' rights in the United States was developed in 1970 by the Plant Variety Protection (PVP) Act. The Act introduced patent-like intellectual property protection for sexually reproducible plants through PVP certificates which afford exclusive rights to the varieties' owners for 20. In 1980, the landmark US Supreme Court case Diamond v. Chakrabarty ruled that living organisms, including genetically modified microorganisms, are patentable. The patent protection extended to plants and plant seeds in 1985 (Clancy and Moschini, 2017). The use of patents for corn and soybean varieties has grown at an faster pace since their introduction in the 80s and has surpassed PVP certificates since the mid-2000s. A recent study by Moscona (2021) has shown that patent protection accelerates the development of novel plant varieties. Counties more exposed to patent laws because of their crop composition also see an increase of land value and profit. Furthermore, the ownership of the patents is concentrated in a handful of firms. DuPont and Monsanto owned a combined total of 88% of corn utility patents and 77% of soybean utility patents between 2011 and 2015 (Clancy and Moschini, 2017).

The confluence of genetic engineering and IPR in the seed industry is best captured by the rise of the former seed giant Monsanto. Monsanto commercialized the first GM varieties in 1996. Monsanto was not in the seed business before the adoption of genetic engineering in agriculture. It invested heavily in the R&D of GM traits and quickly captured the seed market through its GM traits in commercialized varieties of soybeans, cotton, and corn. The investment in R&D is accompanied by aggressive acquisitions of other seed companies, in which Monsanto acquired a broad germplasm base. Monsanto also licensed its GM traits to other seed companies to achieve wider adoption. In the 2000s, Monsanto's GM traits dominated the corn, soybean and cotton seed market. In 2000, according to its own account, Monsanto's traits occupied 21.8% of total planted acres of corn and 60.4% of soybean, and in 2009, these figures grew to 81.1% and 94.5%, respectively (Moschini, 2010).

The concentration in the seed markets has long been noted and has continued to unfold into the present. In the past three decades, the seed market has seen the emergence of the Big Six (Monsanto, Syngenta, Bayer, DuPont, BASF, and Dow Chemical), which integrates both seed and agrochemicals (except for BASF, which focuses on agrochemicals). Three recent mergers have furthered the concentration of the industry and the integration of the seed, biotechnology and agrochemical firms. Since 2015, the merger of Dow and DuPont, the acquisition of Syngenta by ChemChina, and the merger of Bayer and Monsanto have brought the number of the major multinationals to four. In all three mergers, firms with a strong position in agrochemical markets (Bayer, Dow and ChemChina) are combined with firms with a strong focus on seed and biotechnology (Monsanto, Dupont and Syngenta, respectively).

2.3 Hypotheses for Location Choices in Variety Testing Programs

As the private sector R&D continues to grow in volume and impact, private participation in extension programs deserves more attention. With the dramatic transformations in the agriculture sector, the public sector has responded to changes in the public and private R&D in dynamic ways (K. O. Fuglie and Toole, 2014). This thesis contributes to the literature about the role of extension programs in the agricultural R&D landscape. This thesis is the first to analyse companies' participation and decision-making process in the context of variety testing programs. Through variety performance data, this thesis describes the participation trends and identifies key hypotheses and factors in companies' decision-making process.

The methodological choices are guided by two hypotheses about how regional characteristics affect location decisions. The first hypothesis is that companies select locations that maximize crop yields. Since the purpose of the trials is to compare varieties' performances, choosing locations most suitable for achieving optimal yields naturally is the primary factor in location choices. The relevant region-level information is measures of past yield. Companies are likely to pick regions with better yield in the past. Another hypothesis is that planting locations are not solely determined by yield maximization, but also regional market potential: companies choose locations with greater market potential. As Lee and Moschini (2022) have shown, the information variety testing programs provide to the public affects the adoption of new varieties. Since these programs function as information platforms where companies advertise their seeds, it is reasonable to speculate that companies would select locations with more potential customers. I use the proportion of soybean planting acreage to approximate the effect of market sizes, as I discuss in the next section.

A complicating factor in the research is the addition of FIRST as a competitor in the variety testing space. The entrance of FIRST coincides with the decline in participation in UIUC's variety testing program in the 2000s. Therefore, we are led to ask, is FIRST taking business from UIUC? Do companies change their selection strategies after the entrance of FIRST in 2008? Based on these questions, I estimate the choice scenarios based on different time frames (pre- and post-2008) and samples (UIUC only or both programs).

3

Data and Methodology

3.1 Participation in Variety Testing Programs in Illinois

In this study, I focus on two major variety testing programs in Illinois, the University of Illinois Variety Testing program and FIRST. These two are the primary options if companies choose to test their variety at a third-party testing program in Illinois. Both programs publish their variety testing results through their websites, mailing lists and an established local agricultural newspaper, AgriNews. Some farmland management firms also run variety testing services on the land they manage. One such program in Illinois is the First Mid Ag Services, which conducts corn and soybean variety trials on a substantially smaller scale than FIRST and UIUC.

The University of Illinois Variety Testing program has served as the primary third-party variety trial service in Illinois for decades. While most university-affiliated variety testing programs are part of the university extension, the variety testing program belongs to the university's department of crop science. The program is mainly self-sustained through testing fees. A small portion of the program's land belongs to the extension, while the majority are rented from private parties. The program mainly tests soybean and corn varieties, but it has also expanded to include small grains such as wheat and oat, and mostly recently hemp.

FIRST is a private company that offers soybean and corn variety testing across the corn belt and mid-Atlantic regions. FIRST formed as an association of farmers and businesses that offers variety testing for participating companies for a fee. Founded in Illinois in 1997, FIRST now operates in 15 states through 11 field managers. Unlike public-sponsored variety testing programs, which are often run by extension and state-based, FIRST operates across multiple states. Companies can test a variety across multiple states, potentially reaching more farmers.

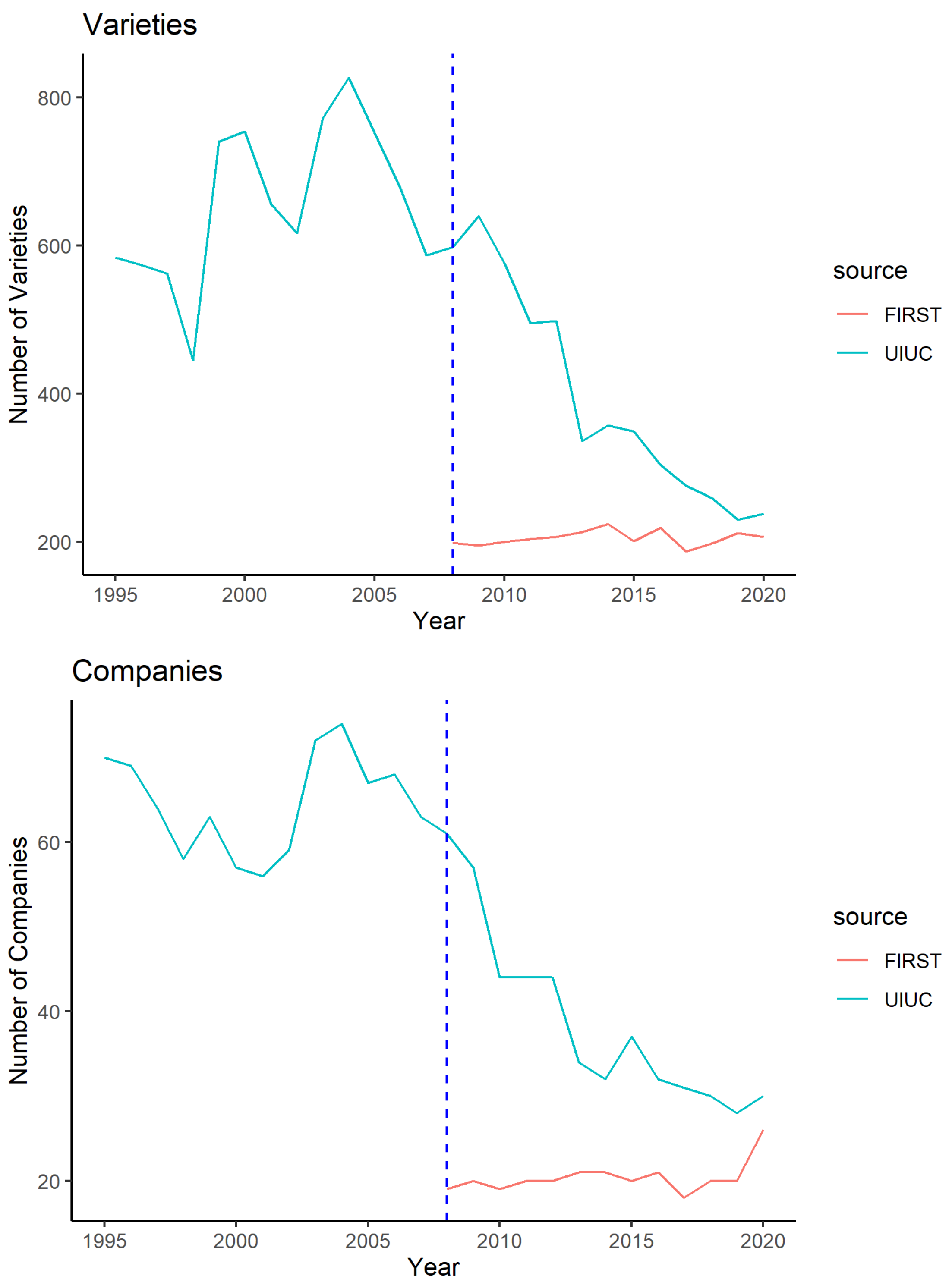

Figure 3.1: Participation in FIRST and UIUC in Illinois from 2000-2015

Figure 3.1 shows the participation in both programs in Illinois from 1995 to 2020. For UIUC's program, both the number of companies and the number of varieties tested declined after their peak in 2002. FIRST starts to publish its variety trials data since 2008. The participation in FIRST remains stable since its inception. Despite the declining participation in UIUC, the number of companies and varieties of FIRST remain low comparing to UIUC's. An important factor for the low participation numbers of FIRST is that the program operates on a national level. The level of participation in FIRST at a national level now exceeds UIUC. In 2018, the aggregate number of soybean varieties tested by FIRST is 686 and the number of companies is 54, while UIUC tested 252 varieties from 21 companies. For seed companies, FIRST offers a more economic option to market their varieties since testing results can reach a national audience. For companies that operate across multiple states, the alternative is to test their seeds at extension programs at every state, which is likely to be more costly.

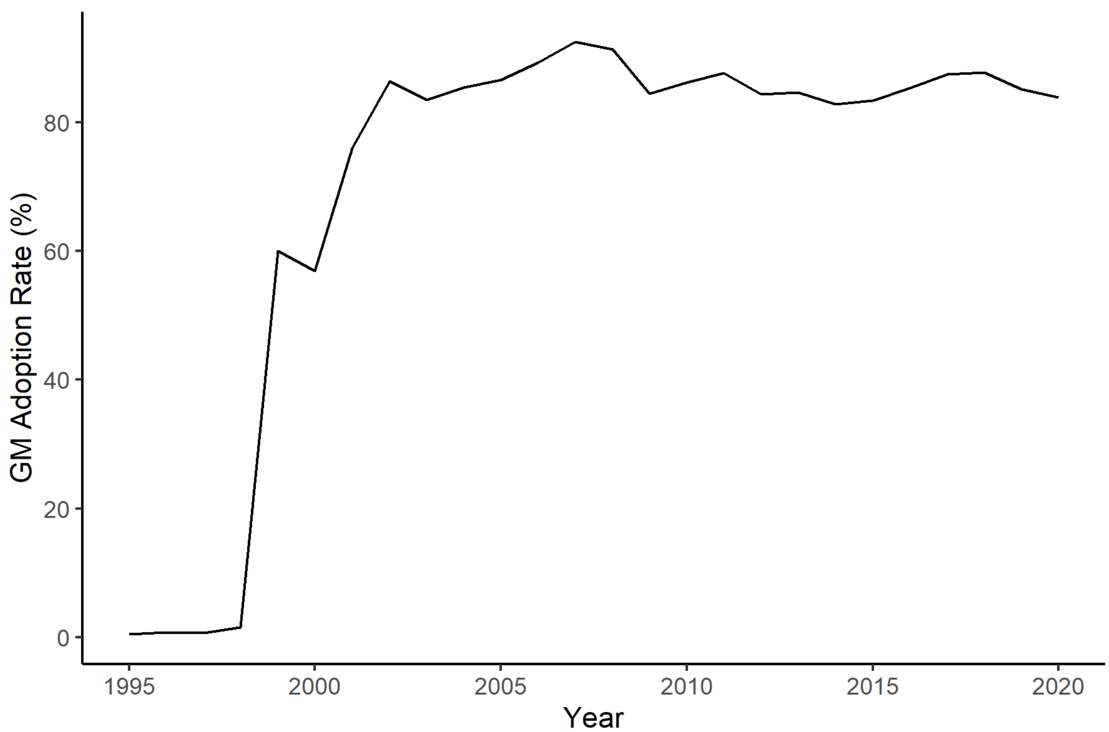

Figure 3.2: GM soybean adoption rate at UIUC from 1995-2020

Figure 3.2 shows GM soybean adoption rate at UIUC's program from 1995 to 2020. Similar to the GM adoption trend described in the previous section, the rate of adoption for GM grew rapidly in the around 2000 and have stayed above 80% since then. On the other hand, FIRST almost exclusively tests GM soybeans since 2008, a time when the adoption of GM is well underway. Compared to FIRST, UIUC tests a sizable number of conventional seeds. Some of these conventional seeds come from regional companies that specialize in non-GM soybeans. It is likely that these firms are more inclined to choose UIUC's program over FIRST since the former is more established regionally compared to FIRST since it has a longer history of working with local companies.

Table 3.1 and 3.2 compare the company compositions of the two program in 2000 and 2015. During this period, there is a significant increase in GM adoption. For UIUC's program, the share of GM soybeans in total number of varieties increase from 59.3% to 81.9% from 2000 to 2015. FIRST started publishing its test results in 2008 and has almost exclusively tested GM varieities. As shown in 3.2, the share of GM crops remains stable after 2005. A number of local seed companies that specialize in non-GM varieties participate in UIUC's program, making up 9.2% of total submissions in 2015. In terms of participation, there is a decrease in the participation of regional companies and an increase in multinational companies in UIUC's program. In 2000, 90.3% of varieties were submitted by regional seed companies, while in 2015, this number decreased to 59.9%. The total number of varieties tested by UIUC's program shrunk by more than half, from 743 to 349. Furthermore, the decrease in variety submissions from regional companies surpassed the decrease in total submissions since more multinational companies enter the program and together they submit more varieties in 2015 than in 2000. The decline in the participation of the regional companies can be partly attributed to acquisitions. A number of regional companies, such as Dairyland and Kruger, that participated in 2000 were acquired by multinationals like Monsanto and DuPont. On the other hand, participation in FIRST has changed little since its entrance in 2008. In 2015, FIRST tested less varieties in Illinois than UIUC, despite UIUC's decline in participation. The compositions of companies for FIRST and for UIUC were similar in 2015. Many companies submited to both services, with a notable exception of Syngenta, which only submits to FIRST.

Company	Number of Varieties	Share of GM (%)	Share of Total Submissions (%)
Advanta - Garst, AgriPro	29	58.5	3.8
AgReliant - LG Seeds, Great Lakes Hybrids	27	63.0	3.6
Monsanto - Asgrow, Dekalb Genetics	17	100.0	2.3
Regional - Kruger, Growmark, Wilken, Dairyland	681	58.1	90.3
Total	754	59.3	100.0

Table 3.1: Variety by Companies from UIUC's Program, 2000

3.2 Variety Performance Data

The variety testings results consist of varieties' traits, performance metrics based on test sites and varieties, information about planting practices, weather and soil type of each region. The most important performance

Company	Number of Varieties	Share of GM (%)	Share of Total Submissions (%)
UIUC			
Monsanto - Stone, Asgrow	52	94.2	14.9
BASF - Credenz	24	1.0	6.9
DuPont - Pfister, AgVenture	42	92.9	12.0
Nutrien - Dyna-Gro	22	90.9	6.3
Regional - Growmark, Steyer	209	73.7	59.9
Non-GMO (included in Regional) - Illini, Blue River	32	0.0	9.2
Total	349	81.9	100.0
FIRST			
Monsanto - Stone, Asgrow	20	100.0	10.0
DuPont - Pfister, Dairyland	50	100.0	24.9
Nutrien - Dyna-Gro	13	100.0	6.5
Agreliant - LG Seeds	12	100.0	6.0
Syngenta - NK Brand	10	100.0	5.0
Regional - Growmark, Steyer	96	100.0	47.8
Total	201	100.0	100.0

Table 3.2: Variety by Companies from FIRST and UIUC, 2015

metric is yield. Also available are content measures of the grain (moisture, oil, protein) and lodging (percentage of plants leaning more than 45 degrees from vertical at harvest). The performance metric serves as a reference for farmers' seed purchase decision, as the tested varieties are put on the market the following planting season. Also available are detailed information about varieties, such as maturity, seed treatment, genetically engineered traits and SCN resistance. Unlike UIUC, FIRST only publishes yield information for top performed varieties. Table 3.3 presents summary statistics for variety traits.

The variety results are published in a timely manner to facilitate farmers' planting decisions. The main channels of distribution are programs' websites, mailing lists and the regional agricultural newspaper, AgriNews. The data are published immediate after harvest in October and November. The trial results facilitate farmers' seeds purchase for the following season, which starts in April and May of the following year.

The testing sites in UIUC' s variety testing program are categorized into a number of regions each consists of several sites. The regions are numbered from Northern to Southern Illinois, with Region I in the north and Region V or VI in the south. Site locations in FIRST are arranged across the state in a similar manner. The plot locations have remained relatively stable over time. The 2015 site locations from the two programs are mapped in Figure 3.3. As shown in their respective regional definitions in Table 3.4, both programs have five regions, while FIRST has more testing sites than UIUC.

The division of regions is mapped onto soybean's maturity groups. Defined along the latitudinal zones,

		Count	Mean(%)
UIUC			
Maturity	Maturity Group 1	64	0.7
	Maturity Group 2	3052	32.2
	Maturity Group 3	4046	42.6
	Maturity Group 4	2171	22.9
	Maturity Group 5	158	1.7
GM Trait	Conventional	1461	15.4
	Genetically Modified	8030	84.6
	Total	9491	100.0
FIRST			
Maturity	Maturity Group 1	7	0.3
	Maturity Group 2	1016	38.1
	Maturity Group 3	1115	41.8
	Maturity Group 4	528	19.8
GM Trait	Conventional	9	0.3
	Genetically Modified	2657	99.7
	Total	2666	100.0

Table 3.3: Soybean Variety Summary Statistics, UIUC (2000-2015) and FIRST (2008-2015)

the maturity group defines where a soybean variety is best adapted based on photoperiod and temperature (Mourtzinis and Conley, 2017). Maturity group ranges from 000 for early maturing varieties to 10 for latest maturing varieties. According to Mourtzinis and Conley (2017), the optimal maturity group of Illinois ranges from MG 2 to MG 4, as shown in Figure 3.4. The maturity groups are highly correlated with the variety testing programs' regional divisions, as shown in Table 3.5 and Table 3.6. The range of maturity groups of the tested varieties spans from MG 1 to MG 4 and 5, with the majority belongs to MG 2 to MG 4. Within each region, most varieties belong to one maturity group, while the rest fall into the adjacent maturity groups.

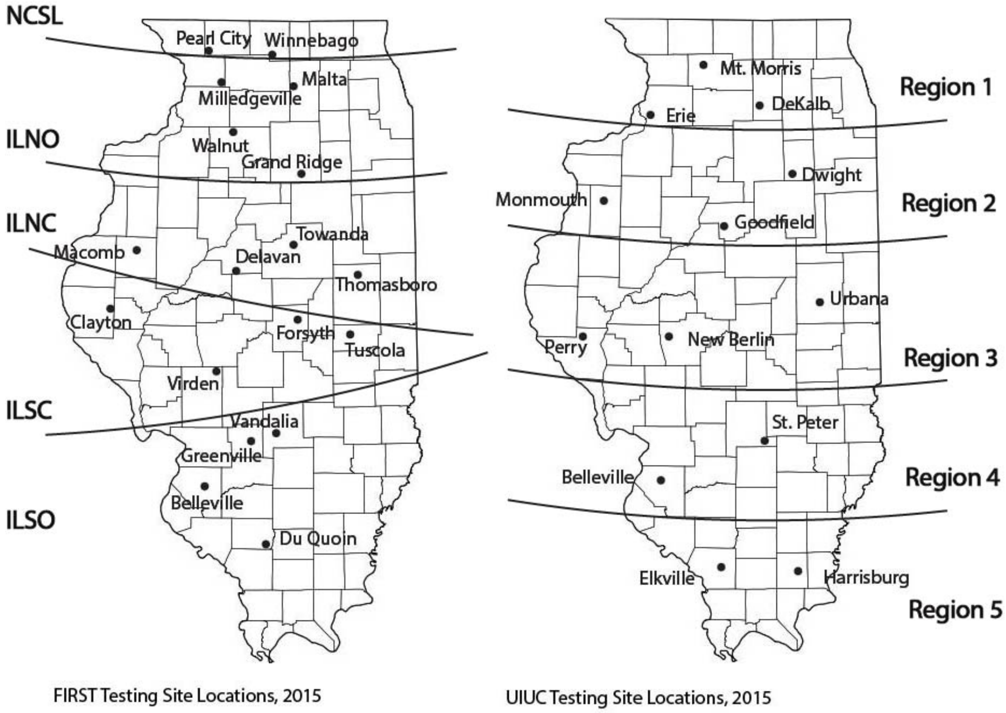

Figure 3.3: Testing Site Locations from Variety Testing Programs in 2015

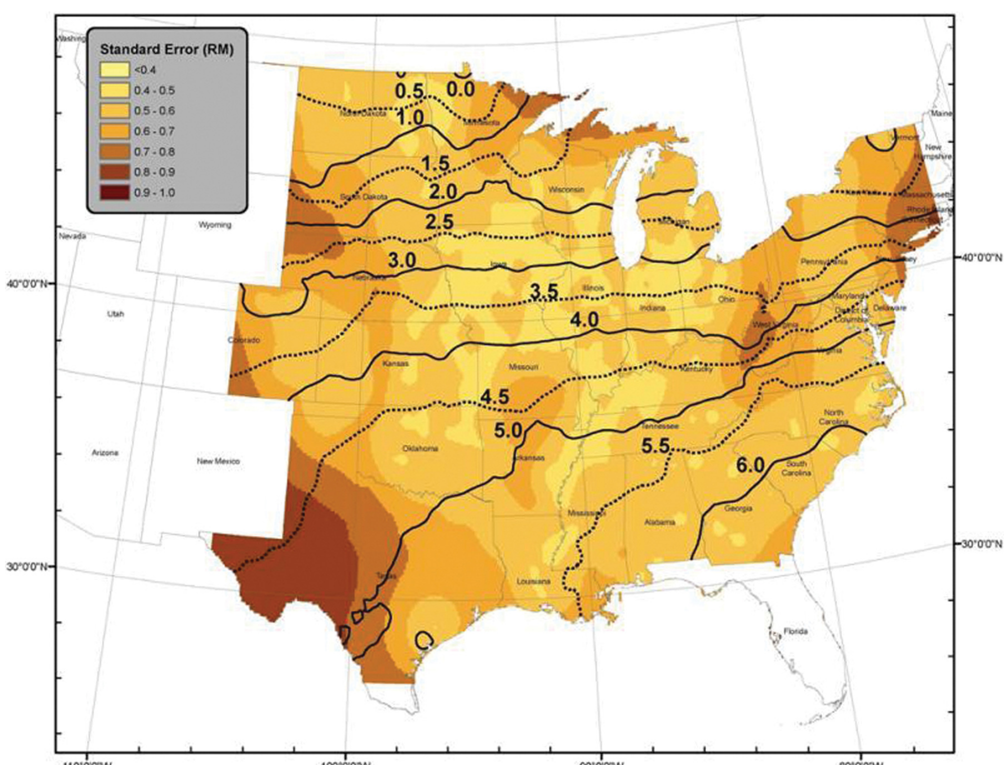

Figure 3.4: Optimal Soybean Maturity Group (Mourtzinis and Conley, 2017)

Region	Location
FIRST	
NCSL	Pearl City, Winnebago
ILNO	Milledgeville, Malta, Grand Ridge, Walnut
ILNC	Macomb, Delavan, Towanda, Thomasboro
ILSC	Virden, Clayton, Forsyth, Tuscola
ILSO	Greenville, Vandalia, Belleville, Du Qoin
UIUC	
Region 1	Mt. Morris, Dekalb, Erie
Region 2	Monmouth, Goodfield, Dwight
Region 3	New Berlin, Perry, Urbana
Region 4	Belleville, St. Peter
Region 5	Elkville, Harrisburg

Table 3.4: Testing Site Region and Location List, 2015

To participate in UIUC's variety testing program, companies submit varieties and choose regions each variety will be tested. The program charges a fee per variety based on the number of locations across the regions. For example, in 2015, the fee was $90 per location. If a company submitted a variety to test in regions 1 and 2, which had a total of 6 locations, it would pay $540 for that variety. The testing fee is charged regardless of the type of varieties for the majority of the time, with the exception of the period between 1997 and 2001, when a higher price was charged for roundup ready (GM) varieties per location. The submission fees for FIRST is not clear.

Region	MG 1	MG 2	MG 3	MG 4	MG 5
Region 1	64	2318	445	0	0
Region 2	0	653	1754	13	0
Region 3	0	80	1439	282	0
Region 4	0	1	353	1447	0
Region 5	0	0	55	429	158

Table 3.5: Distribution of Maturity Groups (MG) by Region from UIUC, 2000-2015

Region	MG 1	MG 2	MG 3	MG 4
NCSL	7	459	0	0
ILNO	0	456	97	0
ILNC	0	101	678	0
ILSC	0	0	311	151
ILSO	0	0	29	377

Table 3.6: Distribution of MG by Region from FIRST, 2008-2015

3.3 The Location Choice Model

I develop a conditional logit model for the location choices of individual seed varieties based on seed's traits and regions' climate and yield records. Our analysis focuses on varieties' planting decisions within Illinois from FIRST and UIUC from 2000 to 2015.

The primary analysis focuses on planting data from UIUC's variety testing program from 2000 to 2015. I estimate a conditional logit model for location choices. Then I use FIRST-only and UIUC and FIRST combined data for a more complete picture of the variety testing services in the state. In this section, I first introduce the conditional logit model and its assumptions. Then I describe the parameters for model estimation based on the hypotheses from the previous section.

In our location choice model, a variety i will be planted among n locations, indexed by j, $j = 1, ..., n$. Following Train (2003), under the assumption of utility-maximizing behavior of the decision maker, the utility of a location choice j for variety i is U_{ij}. The utility of the location choice can be divided into attributes that a researcher can observe V_{ij}, and those they cannot observe ϵ_{ij}. Thus we have:

$$U_{ij} = V_{ij} + \epsilon_{ij} \tag{3.1}$$

Choosing location j over k means one derives greater utility from location j. Therefore, we have:

$$\begin{aligned} U_{ij} &\geq U_{ik} \\ V_{ij} + \epsilon_{ij} &\geq V_{ik} + \epsilon_{ik} \\ \epsilon_{ij} - \epsilon_{ik} &\geq V_{ik} - V_{ij} \end{aligned} \tag{3.2}$$

Conditional logit model assumes that the unobserved terms ϵ_{ij} are identically and independently drawn (iid) from a Type I Extreme Value distribution, and the choice probabilities take the form:

$$\Pr(U_{ij} > U_{ik}, \forall k \neq j) = \frac{\exp(V_{ij})}{\sum_k \exp(V_{ik})} \tag{3.3}$$

The assumption that ϵ_{ij} is iid means that the unobserved factors are uncorrelated over alternative. This can be a restrictive condition in some cases, particularly if the location choice is sequential. In our case, companies' past decision not to test varieties in certain regions will likely affect their decisions in the following years. This condition is also restrictive if there are different levels of substitution in the choice set. For example, if we consider the location choice set to be UIUC and FIRST combined, then iid means that if a region in UIUC's program is not available for planting, one is equally likely to choose regions from FIRST as from alternatives from UIUC. This property of the logit model is called independence from irrelevant alternatives (IIA), which states that the relative odds of choosing i over k are the same no matter what other alternatives are (Train, 2003).

To implement the discrete choice problem, we need to parameterize the observed component of the choice utility, V_{ij}. Following the hypothesis from the previous section, I explore two groups of explanatory variables: one that characterises variety traits and another regional characteristics:

$$V_{ij} = \boldsymbol{Z}_{ij}\gamma + \boldsymbol{X}_i\beta_j \tag{3.4}$$

where $\boldsymbol{Z}_{ij}$ is a vector of regional characteristics for region j and variety i and γ contains the effects of regional characteristics. $\boldsymbol{X}_i$ is a vector for variety-level characteristics that are invariant across regions and β_j contains the their effects on region j relative to the base alternative. Each of the regional characteristic falls into one of the two hypotheses from the previous section: first, companies select locations where varieties can achieve optimal yield; second, companies select locations with greater market potential.

Regions' past yield measures, regional precipitation and growing degree days (GDD) are factors companies might take into account to attain maximum crop yield. Regional weather measures include regional precipitation and GDD (accumulated temperature for plant growth) from the previous year. The regional weather data is developed by Yun and Gramig (2019), which provides county-level climate data from PRISM (Parameter-Elevation Relationship on Independent Slopes Model). At the regional level defined by each variety testing program, I aggregate county-level data points (precipitation and GDD at 50 °F level, respectively) by averaging all counties where the testing sites are located. Finally, I include two yield measures from the previous year that companies might taken into consideration: the lagged average of county-level soybean yield and the lagged average of testing plots yield.

The second hypothesis add one additional parameters. To approximate regional market potential, I use the rolling average of the proportion of soybean production area in all agricultural land of the region over past the three years. Soybean planting area can approximate the market demand of a region. Because of the common practice of corn and soybean rotation, the soybean planting area can change dramatically from the previous year. Therefore, I use the rolling average of the proportion of soybean production area to account for this practice. Finally, I also include program fees as a factor in region selection, which varies depending on the number of locations in a region.

To control for the effect of variety-level traits on location choices, I include varieties' maturity group and GM traits. Because of its role in defining the optimum latitudinal zones for crop growth, the maturity group is among the primary factors in farmers' seed choices (Nafziger, 2009). Planting crops in appropriate regions is a prerequisite for plant growth. As shown in Table 3.5 and Table 3.6, there is a strong correlation between regions and varieties' maturity groups. In addition, we assume GM traits also play a role in companies' location selection process.

In discrete choice models, the choice set must satisfy three conditions: mutual exclusion, exhaustive, and finite (Train, 2003). In our case, variety testing programs offers a finite number of region choices, and the combination of which are all the possible options to choose from, therefore the last two conditions are satisfied. However, the criteria of mutual exclusion is a restrictive condition for our case, since a company usually choose multiple locations to test a variety. In this case, I regard decisions by company to be individual selections, each with one choice region, instead of making multiple choices at once.

4

Results

Table 4.1 and Table 4.2 present the estimation results from UIUC's variety testing program. In the estimation, I use region 2 (the region with most varieties) as the base alternative. The estimation is divided into three time frames, from 2000 to 2015, from 2000 to 2007 and from 2008 to 2015. The latter two periods are separated by the entrance of FIRST in 2008. In the estimation, I removed varieties from maturity group 1 and 5 since the number of varieties in these two groups are small. The estimation results are split into regional characteristics and variety level traits as presented in equation 3.4.

For control variables, as expected, maturity group is a statistically significant across three time periods. In the estimation, I use maturity group 3 as the base maturity group. As shown in the Table 4.2, maturity groups affect location decisions in similar directions across three time frames. For varieties of maturity group 2, it is more likely to be planted in region 1 and less likely in region 3 and 4 in comparison to maturity group 3 in region 2. For varieties of maturity group 4, it is more likely to be planted in region 3, 4 and 5 in comparison to maturity group 3 in region 2. This pattern coincides with the planting pattern shown in Table 3.5. Also, since maturity group 2 is not planted in region 5, region 5 is not statistically significant for maturity group 2 and similarly for maturity group 4 in region 1.

Being GM is not a significant determinant for location selections from 2000 to 2007, but significant between 2008 and 2015. The earlier period coincides with the rapid adoption of GM. Since GM is not significant in this period, it is plausible that the adoption of GM has no geographical preferences. In the latter period, however, GM seeds are more likely to be planted in region 1 and less likely in regions 4 and 5 in comparison to region 2. However, since region 1 has few varieties over the years, it is unlikely to be part of a significant pattern. Comparing regions 2 to 4, the results suggest that there is a higher number of conventional varieties in region 2 comparing to region 4. This is likely due to the fact that there are a limited number of regional companies that specialize in non-GM soybeans in the latter period and these companies tend to test conventional varieties in region 2.

For regional characteristics that are of interest to this study, only the percentage of soybean planting area turns out to be a significant factor in location choices. The two yield measures and weather records are not statistically significant, as shown in the Table 4.1. The lone significant parameter, the proportion of soybean planting area, indicates that as the proportion of soybean planting area increase in the region, it is less likely to be selected by companies to test soybean seeds. The seemingly counter-intuitive results make sense in the following scenario: companies market more aggressively in regions that plant less soybean in proportional terms. Here, companies might view regions with less soybean production as having greater market potential. Yet, neither is it a consistently significant factor, since it becomes insignificant from 2008 to 2015.

The estimation results are fairly consistent before and after the entry of FIRST in 2008. It is likely that the entrance of FIRST has not significantly altered firms' location selection process. As described above, the decline in participation in UIUC's program is not accompanied by an increase in participation in FIRST within Illinois. While it is easy to contribute the the decline to the entrance of FIRST, a few other factors might as well be more impactful. For example, it is possible that companies are giving up on variety testing service altogether, as farmers increasingly rely on private sources of information such as crop advisors and company representatives. Also, it could be that companies are switching from individual state extension programs to FIRST on a national scale. Nationwide, participation in FIRST has surpassed UIUC's variety testing program. It is likely more economic for large firms to achieve a national audience through FIRST compared to individual state-wide programs.

Table 4.3 presents the estimation results from FIRST's variety testing program, with region ILNC as the base alternative.[1] Again, maturity group 3 is the reference maturity group. Similar to UIUC's case, maturity group also plays a significant role in location selections. Compare to maturity group 3 of the base region, varieties with maturity group 2 are more likely to be planted in regions north to the base region. None of the parameters for maturity group 4 is significantly different from zero, since no such varieties are planted in the base region. Based on Table 3.6, most regions have two maturity groups, whereas in FIRST, each region has three. This suggests that maturity group likely plays an even greater role in location selections for FIRST, since each region is associated with a smaller range of maturity groups. Similarly, in the combined model of both programs, the results exhibit a similar pattern in terms of maturity group, as shown in Table 4.4. In this case, region 2 is used as the base alternative for all regions in UIUC and FIRST and maturity group 3

[1] In FIRST's case, there are several data points missing: varieties' yield, testing fees, and regional yield from several years. Also, since FIRST almost exclusively test GM varieties, being GM is not taken into account.

as the base maturity group. The results suggest that for a variety of maturity group 2, it is more likely to be planted in region 1 and NCSL, which are north of the base region, and less likely to be planted in region 3, 4 and ILNC, which are south of the base region. For a variety of maturity group 4, it is more likely to be planted in regions south of the base region and less likely to be planted in regions north of the base region.

	2000-2015	2000-2007	2008-2015
Growing degree days	0.03	0.06	−0.05
	(0.03)	(0.05)	(0.07)
Precipitation	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)
Average county yield	0.00	0.01	−0.01
	(0.00)	(0.01)	(0.01)
Average plot yield	−0.00	−0.00	0.00
	(0.00)	(0.00)	(0.00)
Fees	−0.00	−0.00	
	(0.00)	(0.00)	
Proportion soybean area	−1.62***	−1.87**	−0.00
	(0.37)	(0.65)	(1.08)
AIC	35629.29	19990.50	15636.70
Log Likelihood	−17792.64	−9973.25	−7797.35
Num. obs.	15308	8645	6663
K	5	5	5

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 4.1: Estimation Results for UIUC's Variety Testing Program, Regional Characteristics (Region 2 as base region, maturity group 3 as the base group)

	MG 2	MG 4	Genetically Modified
2000-2015			
Region 1	2.00***	-17.06	0.24**
	(0.06)	(3040.38)	(0.07)
Region 3	-1.36***	2.78***	-0.03
	(0.06)	(0.28)	(0.06)
Region 4	-5.51***	5.34***	-0.25**
	(0.50)	(0.28)	(0.08)
Region 5	-21.76	6.23***	-0.25**
	(2765.54)	(0.28)	(0.10)
2000-2007			
Region 1	2.05***	-17.39	0.13
	(0.09)	(4247.75)	(0.09)
Region 3	-1.42**	2.14***	0.11
	(0.07)	(0.33)	(0.08)
Region 4	-5.39***	4.90***	0.05
	(0.58)	(0.32)	(0.11)
Region 5	-21.87	5.70***	0.09
	(3505.14)	(0.32)	(0.13)
2008-2015			
Region 1	1.94***	-15.39	0.63***
	(0.09)	(2629.16)	(0.13)
Region 3	-1.29***	3.76***	-0.24*
	(0.09)	(0.58)	(0.10)
Region 4	-5.84***	6.14***	-0.64***
	(1.00)	(0.58)	(0.12)
Region 5	-20.59	7.17***	-0.73***
	(2716.28)	(0.58)	(0.15)

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 4.2: Estimation Results for UIUC's Variety Testing Program, Variety Traits (Region 2 as base alternative, maturity group 3 as the base group)

	Maturity Group 2	Maturity Group 4
NCSL	8.20***	6.11
	(1.01)	(19609.78)
ILNO	2.89***	1.11
	(0.16)	(19605.91)
ILSC	-20.53	23.70
	(3707.10)	(13865.78)
ILSO	-18.89	26.69
	(3706.61)	(13865.78)
AIC	4850.86	
Log Likelihood	-2412.43	
Num. obs.	2527	
K	5	

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 4.3: Estimation Results for FIRST, 2008-2015 (ILNC as base alternative, maturity group 3 as the base group)

	Maturity Group 2	Maturity Group 4	GM
Region 1	1.88***	-17.78	0.66***
	(0.08)	(6457.61)	(0.13)
Region 3	-1.35***	3.58***	-0.25**
	(0.08)	(0.45)	(0.10)
Region 4	-6.12***	5.88***	-0.58***
	(1.00)	(0.45)	(0.12)
Region 5	-21.97	6.95***	-0.63***
	(4779.38)	(0.45)	(0.14)
NCSL	6.45***	-12.64	22.98
	(0.71)	(6349.62)	(10284.85)
ILNO	1.66	-17.29	4.04***
	(0.09)	(6339.46)	(0.71)
ILNC	-1.26***	-18.46	22.98
	(0.12)	(6323.93)	(10284.85)
ILSC	-22.87	4.05***	2.44***
	(4898.63)	(0.46)	(0.39)
ILSO	-20.99	7.30***	2.56***
	(4919.51)	(0.46)	(0.59)
AIC		43164.98	
Log Likelihood		-21546.49	
Num. obs.		12794	
K		10	

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table 4.4: Estimation Results for UIUC and FIRST combined, 2008-2015 (Region 2 as base alternative, maturity group 3 as the base group)

5

Conclusion

In this thesis, I study the company participation in soybean variety testing programs in Illinois over the past two decades. In recent decades, agricultural input industry has experienced profound transformations fueled by the rapid growth of the private R&D. The private sector has replaced the public sector as the main source of new crop varieties. The public sector is seeking ways to stimulate and engage with private R&D endeavors. The variety testing programs, part of the agriculture extension system, offer a platform for introducing private varieties to the farming community.

Using variety trials collected by UIUC and FIRST, I use conditional logit models to show that companies select locations that has greater market potential before the entrance of FIRST in 2008. The market potential of a region, approximated by the proportion of soybean production area, has an negative effect on the likelihood of a location being chosen. That is to say, as a location's proportion of soybean production increases, it is less likely to be selected. This might suggests that market potential is perceived as the lack of existing market, or the potential for market expansion.

As a competitor of UIUC's variety testing program, FIRST shows few signs of taking business away from UIUC and companies' choice patterns are similar before and after the entrance of FIRST. Despite the decline of participation in UIUC since the 2000s, participation of FIRST in Illinois remains at a lower level comparing to UIUC. The estimation results of UIUC's trials prior and after the entrance of FIRST are largely consistent. Together, the results show that the entrance of FIRST is not altering the landscape of variety testing services significantly in Illinois, and altogether, less companies are utilizing the service. However, as noted above, market potential ceases to be significant after the entrance of FIRST in 2008. This might suggest a change in companies' selection strategy.

This thesis is the first to study company participation in variety testing programs. Many empirical studies on agricultural extension programs measure their impact in terms of productivity growth and economic benefits (Dinar et al., 2007; Jin and Huffman, 2016; Lee and Moschini, 2022). As the private sector R&D continues to grow, more attention should to be paid to the private sector's engagement in public programs. This study is a step towards understanding the place of an extension program in the increasingly privatized field. A fuller characterization of variety testing programs could utilize market-level information such as seeds purchase data to better account for market potential of regions and further investigate whether alternative definitions of market potential also display the same pattern with the entrance of FIRST. As the present study shows, services traditionally performed by the public sector are seeing private competitors or rendered obsolete as the industry consolidates. Further research should answer the extent to which the decline of state-sponsored variety testing programs can be attributed to private competitors such as FIRST or replaced by private sources of information.

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