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ESTIMATING ADOPTION OF GMO SOYBEANS AND CORN: A CASE STUDY OF OHIO, U.S.A.*

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ABSTRACT

We have conducted a survey of Ohio farmers and attempt to estimate adoption of genetically modified organisms (GMOs) based on Ohio farmer attitudes, beliefs, and behaviors. By doing this, we have identified factors that are significant in the farmer's decision making process of whether or not to adopt GMOs.

KEYWORDS

Biotechnology, Ohio, Soybeans, Corn

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“Biotechnology’s been around almost since the beginning of time. It’s cavemen saving seeds of a high-yielding plant. It’s Gregor Mendel, the father of genetics, cross-pollinating his garden peas. It’s a diabetic’s insulin, and the enzymes in your yogurt....Without exception, the biotech products on our shelves have proven safe.”

U.S. Agriculture Secretary Dan Glickman; March 13, 1997.

Introduction

This statement simply states the United States opinion of biotechnology and genetic modification (GM) of plants as of 1997. While other statements have been made concerning voluntary labeling of non-GM food, the United States still strongly believes in the advantages that can be gained through adoption of genetic modification. Mr. Glickman’s agency, the United States Department of Agriculture, has tracked adoption of GM varieties since their inception.

This paper takes a specific look at just one state’s adoption of genetically GMOs. We will look at Ohio, a state on the eastern edge of the Corn Belt that is a substantial producer of corn and soybeans in the United States. In previous reports, Ohio’s data have been included in Corn Belt statistics. We are interested in looking at Ohio alone. Our objectives for this study include conducting a survey of Ohio farmers regarding GMO use, collecting data on attitudes and beliefs concerning GMO adoption, estimating GMO acreage in Ohio, and investigating factors affecting Ohio farmers’ adoption of GMO seed varieties.

Background

For the past few years, biotechnology has been the primary source of debate in the agriculture industry (Northern Light). Since 1996, when RoundUp Ready soybeans were introduced to the public, farmers have been adopting genetically modified seed varieties at rates faster than ever previously witnessed in agriculture. With the introduction of the

RoundUp Ready soybean, farmers could now apply a single broad-spectrum herbicide over the top of the soybean crop and kill a majority of weeds without harming the beans (Carpenter and Gianessi). This breakthrough promised farmers lower herbicide use, costs and crop damage by minimizing trips across the field. While this was not the first product resulting from modern gene-splicing techniques, it was a product that saw high levels of consumer (farmer) acceptance and adoption. Using particle gun bombardment, researchers at Monsanto were able to insert a gene for Glyphosate tolerance into the soybean seed (Monsanto). Table 1 illustrates adoption rates for major crop producing states as estimated by the United States Department of Agriculture (USDA) for 1996, 1997, and 1998. The adoption rate of GM soybeans in the U.S. increased from 7.4% in 1996 to 44.2% in 1998.

Corn has seen similar adoption trends following the introduction of Bt corn and herbicide resistant corn in 1996 (Biotechnology Industry Organization). Bt corn contains a protein that is deadly to the European corn borer, a major cause of damage in U.S. corn crops. The European corn borer feeds on the leaves and stalks of corn plants, thus weakening the stalk and making harvest difficult. Bt corn contains its own insecticide to prevent damage from this pest (Hyde, Martin, Preckel, and Richard). Herbicide resistant corn has traits similar to soybeans in that a broad-spectrum herbicide can be applied over the corn crop to kill weeds that can rob valuable nutrition from the ground. Again, USDA tracks adoption of GM corn varieties and has published the results shown in Table 1.

TABLE 1. Adoption of GM crops in Major Producing States

Field Crop	Year of first Introduction	% of Estimated Planted Acreage		
		1996	1997	1998
<u>Soybean</u>				
Herbicide-resistant	1996	7.4	17.0	44.2
<u>Corn</u>				
Bt	1996	1.4	7.6	19.1
Herbicide-resistant	1996	3.0	4.3	18.4
Corn Totals		4.4	11.9	37.5

Source: Fernandez-Cornejo, Klotz-Ingram, and Jans.

One common trait of all GMOs produced so far is that there is a technology fee associated with purchase of the seed. The purpose of this is for the life-science companies to recoup their investment in research for the product, given they have a patent on the technology. The technology fees for soybeans and corn can increase the cost of production by up to \$10 per acre (McBride and Brooks). The fee is currently charged on a per unit basis on all product sold in the United States. At the international level, the technology fee is assessed depending on patent law in the country of sale.

Ohio

Ohio is a very important state for United States agriculture. In 1997, Ohio ranked fifth in the country in soybean production and sixth in production of corn for grain. This is despite the fact that Ohio has the second fewest acres of farmland in the important North Central region. This region is defined by the National Agricultural Statistics Service (NASS) and includes Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. Ohio is distinguishable by its dependence on small family farms. This is characterized by the fact that Ohio has the lowest average farm size in the North Central region and is actually more comparable in average farm size to states in the Northeast United States. It is estimated that 21.5% (3,200,000 acres) of Ohio farmland was used for corn production in 1999, while 30.2% (4,500,000 acres) of farmland went toward production of soybeans (Ohio Agricultural Statistics Service). These are by far the largest crop volumes produced in Ohio.

Previous Work

When one considers the genetic modification of farm crops to be a new technology available to them, it seems reasonable to compare this to the adoption of hybrid corn that

occurred from the 1930s through the 1950s. Similar to GM, hybrid seeds were put under much scrutiny and concerns about safety were voiced. In his seminal paper, Griliches investigated factors responsible for regional differences in the adoption of hybrid corn as a new technology in the U.S. One of his primary assumptions was that adoption had three distinct characteristics: an origin, a slope, and a ceiling. His goal was to learn something about the ways in which technological change is generated and propagated in U.S. agriculture. His data were best fit by a logistic model in which observations were not points of equilibrium that may or may not change over time, but points on an adjustment path, moving consistently towards a new equilibrium position (Griliches). In his work, the new equilibrium position to be achieved was the ceiling. This ceiling varied from state to state, as he saw different potential maximum adoption rates based upon economic value of different soil types in different states. Griliches had a logistic growth curve expressed as:

$$(1) P = K / (1 + e^{-(a+bt)})$$

where,

P = percentage of corn planted with hybrid seed,
K = ceiling or equilibrium value,
t = time variable,
b = rate of growth coefficient, and
a = constant of integration.

While at first this appears to be a good model to follow, there are some key differences. Griliches viewed hybrid seed as not being a single invention available to all at once. He had a clear distinction between availability and adoption. Availability started in the Corn Belt and spread outward (Dixon). With GMOs, supply was available throughout the United States. Another significant difference between the work of Griliches and GMO researchers of today is that Griliches did his work in the 1950s and had almost twenty years of data with which to conduct a time series analysis. Today, researchers only have four to five years of data upon which to make estimations. While we do now have more complex methods of estimation, twenty years worth of data would make analysis a simpler task.

More recently, the USDA has undertaken an extensive survey of GMO adoption through the Agricultural Risk Management Study (ARMS). Their survey is a three-part task including: screening, obtaining production practices and cost data, and obtaining financial information. Their 1997 survey for soybeans covered 19 states representing 93% of all soybeans grown in the U.S. They used a total of 1,444 observations from 17 states after further screening of the data. In the paper by Fernandez-Cornejo, Klotz-Ingram, and Jans, a per acre profit function was constructed from the collected data. The profit function included probabilities estimated through a probit analysis conducted to calculate the probability of a farmer using genetically enhanced seed varieties. They ran this model for herbicide resistant soybeans, herbicide resistant cotton, and Bt cotton. While they found no significant change in profit resulting from adoption of GMOs, they did find that elasticity of yield with respect to probability of adoption of herbicide resistant soybeans increased .03. McBride and Books found similar results from the same data set.

Data Collection

For the purpose of this research, we worked with the Ohio Corn Growers Association (OCGA) in developing a sample from which to conduct a survey of Ohio farmers. The National Corn Growers Association in conjunction with numerous agricultural magazines developed the OCGA database. The database contains a vast array of demographics that cover virtually all aspects of production agriculture. The grower information that we used to develop our sample was a random sample of 1,922 Ohio corn and soybean producers.

From the randomly selected 1,922 producers, 600 of these were randomly chosen to receive a mail survey that included general attitude questions regarding GMOs, previous history and future intentions regarding GMOs, and acreage, cost, and price information for 1998, 1999, and 2000. We designed two versions of the survey and divided the sample into

two groups of 300. Both editions of the survey included identical questions regarding attitudes about GMOs and general questions about benefits of and concerns regarding GMOs. In the long edition, producers were asked to fill out a chart with data regarding acreage, seed cost, herbicide cost, insecticide cost, commodity price, and yield for both GMO and conventional varieties for crop years 1998, 1999, and 2000. For the short edition, we only asked growers about the acreage for GMO and conventional corn and soybeans in 1999 and 2000. As an incentive for recipients to complete and return the survey, they were asked to fill out a card that will enter them in a raffle for Ohio State University football tickets (a large incentive in Ohio). Also, the envelopes were marked with labels noting that GMO and Ohio State Football information was inside the envelope.

Of the 600 surveys that were sent in May of 2000, 130 were returned giving a response rate of 21.5%. This response rate was close to our goal as the survey was sent in the middle of planting season in Ohio (Pennings, Irwin, and Good). Due to time constraints of both the recipients and us at the University, limited follow-up was completed in order to raise the response rate.

Of the surveys that were returned, the following descriptive statistics describe demographics of the sample. The average age of the respondents was 47.9 years, with 76 (60.3%) under 50 and 46 (39.7%) over age 50. As for education, 67 (52.8%) had a high school degree or less while 57 (47.2%) had at least some college education. 47 respondents (42.3%) reported income levels over \$50,000 per year. One demographic area in question involves the amount of farmland dedicated to crops. As stated earlier, the average farm in Ohio is reported to be 186 acres in 1999, from the respondents to this survey, the average farm size is 1,218 acres with 43 (39%) being over 1,000 acres. Overall, these data represent farmers who are younger, more educated, and who farm more land than the average. Table 2

compares average farm size and average farmer age among our survey, the Ohio Corn Growers Association (OCGA), and the Ohio Department of Agriculture (ODA).

TABLE 2. Farm Size and Operator Age from different sources.

Variable	OSU	OCGA	ODA
Average Farm Size (Acres)	1,218	>500	186
Average Age of Operator (Years)	47.9	52	53

Source: Ohio Department of Agriculture, Ohio Corn Growers Association

Table 3 shows a summary of statistics gathered concerning farmers' production in 1999 and their responses to a series of questions regarding premiums and segregation of GMOs from non-GMOs.

TABLE 3. Survey Summary Statistics

Questions	Corn		Soybeans	
	Yes	No	Yes	No
Did you plant any genetically modified varieties in Spring of 1999?	52.4%	47.6%	84.3%	15.7%
Did you encounter any elevators that would not accept GM varieties last fall?	4.3%	95.7%	0%	100%
Did you receive premiums for non-GM varieties last fall?	7.0%	93.0%	21.3%	78.7%
Do you plan to segregate GM from non-GM varieties this fall?	18.6%	81.2%	35.5%	64.5%
Do you expect premiums for non-GM varieties this fall?	7.0%	93.0%	22.3%	77.7%

As evident from Table 3, a strong majority of respondents have adopted GMOs on some level. Also notable are the percentages of respondents who expect premiums and plan to segregate soybeans in hopes of finding a niche for their product.

In reference to farmers who have planted some or no GMOs, Table 4 gives a summary of data from the survey we conducted. The results show that the adoption rates in terms of number of farmers were higher for soybeans than for corn. It is also evident that while the number of farmers adopting GM soybeans and herbicide-resistant corn have steadily increased, the number of farmers using Bt corn decreased in 2000.

TABLE 4. Sample Statistics of GMO Adoption

Crop	Item	1998	1999	2000
<i>Soybeans</i>	Number of farmers adopting GM varieties	27 (77.1%)	90 (86.5%)	92 (87.6%)
	Number of farmers not adopting GM varieties	8	14	13
	<i>Total Sample</i>	35	104	105
<i>Corn</i>	Number of farmers adopting only Bt Corn	9 (32.1%)	41 (42.7%)	28 (29.8%)
	Number of farmers adopting only herbicide-resistant corn	0	1 (1%)	6 (6.4%)
	Number of farmers adopting both Bt and herbicide-resistant corn.	0	11 (11.5%)	10 (11.2%)
	Number of farmers not adopting GM varieties	19	43 (44.8%)	50 (53.2%)
	<i>Total Sample</i>	28	96	94

Model

The model chosen for this study loosely follows previous work by Fernandez-Cornejo, Klotz-Ingram, and Jans. While they used a Probit model to estimate probabilities of adoption, and then developed a profit function as a result of the adoption probability, we will use a Tobit model to estimate probability, number and share of acres planted with GMOs. This type of model is a censored regression model as first studied by Tobin in the 1950s. The Tobit model is a two-stage model in which the result of the first stage regression is identical to that of Probit (Maddala; Greene).

Through the Tobit model, we were able to estimate acreage and share of acreage for herbicide resistant soybeans, Bt corn and herbicide resistant corn for 1998,1999,and 2000 planting seasons. Independent variables can be grouped into six categories: cost and profitability, price risk, demographics, safety, environmental, and other. Within each group, there are questions regarding producer attitudes, potential and realized benefits and concerns, previous planting history, and future intentions.

Based upon the frequency of response and distribution of answers, questions that required the respondent to answer on a six-point agree-disagree scale were translated into a

series of dummy variables. Coding was done at three points (1,2,3) for most questions. This typically included a dummy variable if the respondent answered strongly disagree or disagree, a dummy variable if the respondent answered strongly agree or agree, and a dummy variable for the more neutral responses disagree somewhat and agree somewhat. The only agree-disagree question not coded this way was the question that asked, “I would be hesitant to feed babies with genetically modified food.” This question, asked as a measure of perceived safety of GMOs was coded with two dummy variables, one for disagree strongly, disagree, and somewhat disagree, and one for strongly agree, agree, and somewhat agree.

A majority of other variables were measured through the use of dummy variables in order to account for a particular characteristic or practice. For example, under the environmental category, if the respondent marked that lower herbicide use was a benefit of herbicide resistant soybeans a dummy variable was used to indicate this. An abbreviated list of variables used, short descriptions of them, and expected signs are included as Table 5. This list includes some variables that are statistically significant in the 2000 soybean acreage equation. A positive expected sign reflects that possessing this characteristic would increase GMO acreage or share of production. A complete list of variables, including expected signs and sample descriptive statistics, is included as Appendix 1. This includes only the dummy variables used in the model. Dropped dummy variables are not included. Using the question “Farmers are realizing cost savings by using GM varieties” as an example, the dummy variables are as follows: 1 if the respondent signified they agreed or strongly agreed to the statement, 0 otherwise; 1 if the respondent signified they disagreed or strongly disagreed to the statement, 0 otherwise; and 1 if the respondent disagreed somewhat/agreed somewhat to the statement, 0 otherwise. The variable for disagree somewhat/ agree somewhat is not included in the model.

TABLE 5. Variable Description and Expected Signs for 2000 Acreage Estimates

<i>Variable</i>	<i>Description</i>	<i>Expected Sign</i>
<i>Cost and Profitability</i>		
COST2	Farmers are realizing cost savings by using GM varieties.	Positive
PROF	Higher profitability as an advantage	Positive
TILL	Less tillage as a benefit	Positive
YIELD	Yield increase as a benefit	Positive
HERBCOST	Decreased herbicide cost as a benefit	Positive
WEEDCON	Improved weed control as a benefit	Positive
<i>Price Risk</i>		
MKT	Ability to market GMOs as a concern	Indeterminate
CNTRCT	Percentage of Grain that is contracted	Indeterminate
PREM99	Premiums received in 1999	Negative
<i>Demographics</i>		
SOY99	GMO soy planted in 1999	Positive
CORN99	GMO corn planted in 1999	Positive
INC2	Income greater than \$100,00 per year	Indeterminate
EDU2	Education Greater than High School	Positive
NE	Farm in North East Ohio	Indeterminate
NW	Farm in North West Ohio	Indeterminate
OWNS	Percentage of Farm that is owned	Indeterminate
LVSK	Livestock on farm	Positive
<i>Safety</i>		
SCIE2	Scientists have not studied the long-term risks of eating GM foods.	Negative
BABY1	I would not be hesitant to feed babies with genetically modified food.	Positive
<i>Environmental</i>		
RESIS	Resistant weeds as a concern	Negative
HERBUSE	Lower herbicide use as a benefit	Positive
INSCTUSE	Decreased insecticide use as a benefit	Positive
<i>Others</i>		
KNOW2	I consider myself knowledgeable about genetic modification.	Indeterminate
WORM2	I would adopt corn resistant to root worms if it becomes available.	Positive

One independent variable of interest is the region of Ohio in which the farm operates. We divide the Ohio grain producing areas into three sections, the Northwest, Northeast, and Southwest. Average farm size was also computed for each region in order to look for causes for differing adoption rates between regions. While the average farm size overall was 1,218

acres for the 107 respondents who reported farm size, 63 farmers from the Northwest had an average of 1,118 acres, 19 farmers from the Northeast had an average of 1,277 acres, and 25 farmers from the Southwest had an average farm size of 1,432 acres.

As a measure of “goodness of fit,” R^2 is used to describe how well our data fitted the model. R^2 tells us what percentage of variation of the dependent variable our model explains. Table 6 gives the R^2 for each estimate. As evident from this table, our models do an acceptable job of explaining variations of acreage and share, considering that cross sectional data were used. The R^2 range from .306 all the way to .99. Even though the estimated models for 1998 tend to have very high R^2 , the results are highly speculative because of a very small sample size and many wrong signs for the significant coefficients. In fact, in order to run the models for 1998, many insignificant variables were dropped to have sufficient degrees of freedom.

TABLE 6. Estimated R^2 of Regression

Crop	Acre00	Acre99	Acre98	Share00	Share99	Share98
Soybeans	0.63	0.524	0.996	0.619	0.398	0.957
Bt Corn	0.45	0.556	0.98	0.556	0.476	0.306
Herbicide-resistant corn	0.783	0.962		0.719	0.875	

Soybeans

Estimates for soybean acreage and acreage share were run for 1998, 1999, and 2000. Over this time period, the mean acreage of GM soybeans has increased from 209 acres in 1998 to 372.53 acres in 2000. Increases have also been seen in acreage share as the mean value has risen from .41 to .66 this year. Table 7 gives data on average acres and share for all soybeans and corn. For this table, the maximum values were used as an indication of range. This is possible because for all estimates, the lower bound was zero.

TABLE 7. Sample Statistics of GM Acreage and Share of Production^a

<i>Crop</i>	<i>Variable</i>	1998			1999			2000		
		Sample Size	Mean	Max	Sample Size	Mean	Max	Sample size	Mean	Max
GM	Acreage	25	209	850	85	311	1200	83	372.5	3000
Soybeans	Share	25	0.41	1.00	85	0.57	1.00	83	0.66	1.00
Bt Corn	Acreage	25	33.68	500	82	76.72	800	79	64.08	1600
	Share	25	0.10	1.00	82	0.17	1.00	79	0.15	1.00
Herbicide-Resistant Corn	Acreage	b			82	16.64	700	79	29.83	800
	Share				82	0.05	1.00	79	0.07	1.00

a. Sample size refers to the number of observations used for regression analysis.

b. Blanks indicate data not available.

The sample sizes for this table were obtained from the regression results. For example, the GM soybeans 1998 sample size reflects that there were 25 usable observations for estimating acreage and 24 usable observations for estimating share. 1998 sample sizes are much lower because only those respondents completing the long version of the survey were asked to give data from 1998.

When analyzing the results of estimation over the three-year period, it is necessary to observe which variables are statistically significant. Of the variables used, Cost 2, the respondent believing that farmers are realizing cost savings by adoption of GMOs, was significant in the estimation of acreage in 1999 and 2000 as well as for share in 1998, 1999, and 2000. All of the coefficients were positive implying that a belief in cost savings increases adoption. Table 8 summarizes variables that are statistically significant at 10% level or lower in estimating the adoption of GMO soybeans over this period of time.

TABLE 8. Significant Variables in Soybean Estimation

Variables	Acre00	Acre99	Acre98	Share00	Share99	Share98
<i>Cost and Profitability</i>						
COST1			+			+
COST2	+	+		+	+	+
PROF	+	+	+			
HERBCOST						
YIELD				+		
TILL				+		
<i>Price Risk</i>						
MKT			-			
PREM			-			-

CNTRCT	-		+		+
<i>Demographics</i>					
AGE			-		-
INCM1	+		-	+	
INCM2	-	-			
NE			+	+	+
NW			-		-
OWNS			-		
CROPS	+	+	-		-
<i>Safety</i>					
RISK1			-		
SCIE1			+		+
SCIE2			+		+
BABY1	+		-		-
<i>Environmental</i>					
HERB2			+		
RESIS			+		
HERBUSE	+			+	
<i>Other</i>					
KNOW1	-	-		-	
KNOW2			+		+
WORM1				-	
WORM2		+	-		

Interpretation of these results can be simplified to the following, if a farmer considers himself to not be knowledgeable about GMOs, or has income below \$20,000 per year, he will be less likely to adopt GMO soybeans. If a farmer believes that cost savings can be achieved, or that GMO soybeans lead to higher profitability, they will be more likely to adopt. It is noted that cost savings have stronger impacts than profitability, as the profitability is not significant at all in the acreage share equations. While there are conflicting results when interpreting the effect of the number of acres of total crops on GMO adoption, it is proposed that the relationship is positive despite the 1998 estimated coefficients. Complete regression results from the soybean estimation for 2000 are included in the Appendix Tables 2-3.

Bt Corn

Similar to GMO soybeans, estimates of Bt corn adoption were obtained for 1998, 1999, and 2000 again using both acreage number and share as dependent variables (See

Appendix Tables 2-3 for complete results). Unlike GMO soybeans, which have seen steady growth in average acreage and share, Bt corn average acreage and share, in parenthesis, increased from 33.68 (.10) to 76.72 (.17) from 1998 to 1999, but then decreased in 2000 to 64.08 (.15). While some of this decrease can be related to decreased expected infestation levels of the European corn borer, we wanted to investigate what factors also influenced the farmers' decision to adopt. When compared with GMO soybeans, it is possible to find more variables that are significant across years.

TABLE 9. Significant Variables in Bt Corn Estimation

Variables	Acre00	Acre99	Acre98	Share00	Share99	Share98
<i>Cost and Profitability</i>						
COST1		+		+	+	
COST2				+		
YIELD	+	+		+	+	
INSCTCON	+			+		
<i>Price Risk</i>						
MKT	+					
PREM				-		
CNTRCT	+		-	+		
<i>Demographics</i>						
HERBPROD	+			+		
AGE		+				
INCM1	-	-	+	-	-	+
NE			+	+		
NW				+		
CROPS	+	+	+			
<i>Safety</i>						
RISK2		+			+	
SCIE1			+	+		+
SCIE2		-	-		-	
<i>Environmental</i>						
HERB2		+			+	
RESIS		+			+	
INSCTUSE			+	+		
<i>Other</i>						
WORM1					-	
WORM2	+	+	+	+		

Some key differences can be noted between factors that affect adoption of Bt corn when compared with GMO soybeans (Table 8). Most important of these is the significance of income. While for soybeans, income under \$20,000 (Inc1) was negatively related to GMO

adoption, for Bt corn, income above \$100,000 (Inc2) was negatively related. This result implies that farmers with a very high income would not adopt as much Bt corn as those with lower income levels. Also of significance is the strong relationship between adoption of Bt corn and the respondents answer to the question, “I would adopt corn resistant to root worms (another corn pest) if it becomes available.” There is a strong positive relationship between the respondent agreeing to this question and adopting Bt corn.

While not a significant variable, it is worth mentioning that the more grain that the farmer forward contracts, the more Bt corn he is estimated to grow. When the level of forward contracting is used as a measure of risk, with high levels of contracting representing a farmer being risk adverse, this sign is consistent with theory. Bt corn is often looked at as an insurance policy for the farmer. In the case of high levels of infestation, they are protected from the pest, if low infestation occurs, the technology fee is seen as the insurance premium. Therefore, the more risk averse a farmer is, the more likely they should be to adopt Bt corn in cases where infestation levels of the European corn borer are expected to be a problem for the crop.

The results also show that cost savings were significant in Bt corn equations. Regarding this, it is important to mention that COST1 and COST2 represent change in comparison with the dropped variable, not necessarily a direct change in cost. The profitability variable was not significant at all. These results imply that cost or profitability play less important role in the adoption of Bt corn than GM soybeans.

Herbicide-Resistant Corn

While our sample included no observations of herbicide-resistant corn adoption in 1998, we can look at variables that influenced adoption in 1999 and 2000 (see Appendix Tables 2-3 for complete sets of regression results). Then we can further analyze similarities

and differences between adoption of herbicide-resistant corn and Bt corn. As evident from Table 10, adoption of herbicide-resistant corn has increased, but not at the rate of either Bt corn or GMO soybeans, reaching only an average acreage of 29.83 and average share of .07 in our sample.

TABLE 10. Significant Variables in Herbicide-Resistant Corn Estimation

Variable	Acre00	Acre99	Share00	Share99
<i>Profitability</i>				
WEEDCON			+	
<i>Price Risk</i>				
MKT		+		
CNTRCT	-	-	-	-
<i>Demographics</i>				
BTPROD	+	+	+	
INCM1				-
NE	+		+	
NW			+	+
CROPS	+			
<i>Safety</i>				
RISK1				-
SCIE1		+		+
SCIE2		+		+
BABY1		+		
<i>Environmental</i>				
HERB2	-	-		
RESIS		-		
<i>Other</i>				
KNOW1	-	+		+
KNOW2		+		+
WORM2		+	+	+

As evident from Table 10, adoption of herbicide-resistant corn is positively related to the adoption of Bt corn. The variable BTPROD measures the relationship that Bt adoption has on herbicide-resistant adoption. The signs of HERB2, strongly agree or agree that GMOs lead to reduced herbicide and insecticide use, appear to contradict the theory that reduced herbicide use would lead to greater adoption.

When compared with Bt corn, herbicide-resistant corn is similar in that adoption is positively related to willingness to adopt rootworm tolerant corn if it comes onto the market. This variable was used to measure willingness to adopt technologies that are still in

development stages. Of the 124 respondents who answer this question, 77 either agreed or strongly agreed that they would adopt rootworm tolerant corn.

Being located in the Northeast part of Ohio is another variable that is significant for both Bt and herbicide-resistant corn in 2000. For this variable, NE, being located in this demographic area results in higher adoption of both corn varieties. On the other hand, the level of forward contracting is inversely related to the amount to herbicide-resistant corn that is grown. This is in contrast to the positive relationship that was seen with Bt corn. Again using forward contracting as a measure of willingness to accept risk, this distinction is theoretically correct. While adoption of Bt corn was seen as a risk adverse decision, adoption of herbicide-resistant corn can be viewed as risk seeking. Herbicide-resistant corn allows the farmer a greater level of convenience of pest control. They are able to use a broad-spectrum herbicide to rid the field of pests. In this light, they are risk seeking in the hope that the value of convenience is greater than the associated technology fee.

Conclusions

This paper presents preliminary work being done on GMO adoption in Ohio. Our objective is to analyze factors that are significant in the estimation of GMO adoption. From the results presented, it is apparent that several factors are significant over time in estimating adoption. The work being conducted for this project is very new. Attempts have been made to find other research that has attempted to estimate GMO adoption as a function of attitudes, perceptions, and behaviors, but none have been found. Again, due to the fact that our research is ongoing, the results should be regarded as preliminary.

Our preliminary estimations have shown that there are consistent factors affecting adoption across years for the same crops as well as across crops during the same year. It has also been found that while the adoption of GM soybeans and herbicide-resistant corn has continued to increase, the adoption of Bt corn decreased in 2000. Monsanto originally

predicted that the convenient GM seed would eventually replace conventional soybeans. Questions for the future on this topic will be primarily concerned with attempting to predict adoption patterns in the future. In order to do this, another survey is being proposed in January 2001 after the 2000 harvest season. This edition would be sent to another 1,000 farmers in Ohio in order to gain an even better understanding of what drives adoption of GMOs.

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APPENDIX 1. Variable Description and Signs for 2000 Acreage Estimates

<i>Variable</i>	<i>Description</i>	<i>Soybeans^a</i>		<i>Corn^b</i>		<i>Expected Sign</i>
		<i># of respondents</i>	<i>%</i>	<i># of respondents</i>	<i>%</i>	
<i>Cost and Profitability</i>						
COST1	Farmers are not realizing cost savings by using GM varieties.	15	15%	14	15%	Negative
COST2	Farmers are realizing cost savings by using GM varieties.	49	48%	40	44%	Positive
PREM99	Premiums received in 1999	24	23%	6	7%	Negative
PROF	Higher profitability as an advantage	37	36%	na	na	Positive
HERBCOST	Lower herbicide cost as a benefit	22	21% ^c	13	14% ^d	Positive
WEEDCON	Improved weed control as a benefit	na	na	36	40% ^d	Positive
YIELD	Higher yield as a benefit	5	5% ^c	27	30% ^e	Positive
TILL	Less tillage as a benefit	8	8% ^c	na	na	Positive
INSCTCON	Improved insect control as a benefit	na	na	20	22% ^e	Positive
<i>Price Risk</i>						
MKT	Ability to market GMO as a concern	69	67%	55	60%	Negative
PREM	Premiums for non-GMO's as a concern	30	29%	25	27%	Negative
CNTRCT	Percentage of Grain that is contracted	na	20%	na	20%	Indeterminate
<i>Demographics</i>						
SOY99	GMO soy planted in 1999	90	87%	na	na	Positive
CORN99	GMO corn planted in 1999	na	na	51	56%	Positive
BTPROD	Bt corn planted	na	na	38	42%	Positive
HERBPROD	Herbicide-resistant corn planted	na	na	16	18%	Positive
AGE ^f	Age in years.	(48.50)	na	(48.50)	na	Negative
INCM1	Income less than \$20,000 per year	11	11%	19	21%	Indeterminate
INCM2	Income greater than \$100,00 per year	12	12%	13	14%	Indeterminate
EDU2	Education Greater than High School	50	49%	46	51%	Positive
NE	Farm in North East Ohio	14	14%	13	14%	Indeterminate
NW	Farm in North West Ohio	50	49%	45	49%	Indeterminate
OWNS ^f	Percentage of Farm that is owned	(0.29)		(0.30)		Indeterminate
CROPS ^f	Acres of land in crops	(1176.00)		(1267.00)		Indeterminate
LVSK	Livestock on farm	51	50%	46	51%	Positive
<i>Safety</i>						
RISK1	Eating genetically modified food is not highly risky.	84	82%	72	79%	Positive

RISK2	Eating genetically modified food is highly risky.	4	4%	4	4%	Negative
SCIE1	Scientists have studied the long-term risks of eating GM foods.	27	26%	23	25%	Positive
SCIE2	Scientists have not studied the long-term risks of eating GM foods.	24	23%	19	21%	Negative
BABY1	I would not be hesitant to feed babies with genetically modified food.	78	76%	66	73%	Positive
<i>Environmental</i>						
HERB1	Farmers are using less herbicide and insecticide by using GM varieties.	3	3%	2	2%	Negative
HERB2	Farmers are not using less herbicide and insecticide by using GM varieties.	71	69%	62	68%	Positive
RESIS	Resistant weeds as a concern	45	44%	36	40%	Negative
HERBUSE	Lower herbicide use as a benefit	17	17%	10	11%	Positive
INSCTUSE	Decreased insecticide use as a benefit	na	na	18	20%	Positive
<i>Other</i>						
KNOW1	I do not consider myself knowledgeable about genetic modification.	8	8%	7	8%	Indeterminate
KNOW2	I consider myself knowledgeable about genetic modification.	45	44%	42	46%	Indeterminate
WORM1	I would not adopt corn resistant to root worms if it becomes available.	6	6%	5	5%	Negative
WORM2	I would adopt corn resistant to root worms if it becomes available.	62	60%	55	60%	Positive

^aBased on the total sample of 103 soybean producing respondents.

^bBased on the total sample of 91 corn-producing respondents.

^{c,d,e}The responses to these questions are mutually exclusive.

^fThe figures in parentheses are sample means.

APPENDIX 2. Variable Description, Expected Signs, and Estimated Coefficients for 2000 Acreage Equations

<i>Variable</i>	<i>Description</i>	<i>Expected Sign</i>	<i>Estimated Coefficients*</i>		
			<i>Soybeans</i>	<i>Bt Corn</i>	<i>Herb-Resistant Corn</i>
<i>Cost and Profitability</i>					
Cost1	Farmers are not realizing cost savings by using GM varieties.	Negative	-216.98	239.23	-144.71
Cost2	Farmers are realizing cost savings by using GM varieties.	Positive	240.06	145.78	174.55
PROF	Higher profitability as an advantage	Positive	106.5		
HERBCOST	Lower herbicide cost as a benefit	Positive	48.41		129.72
YIELD	Higher yield as a benefit	Positive	34.12	418.48	
TILL	Less tillage as a benefit	Positive	130.93		
INSCTCON	Improved insect control as a benefit	Positive		368.34	

WEEDCON	Improved weed control as a benefit	Positive			195.47
<u>Price Risk</u>					
MKT	Ability to market GMO as a concern	Negative	-70.15	180.58	88.78
PRE	Premiums for non-GMOs as a concern	Negative	12.34	-106.2	88.98
CNTRCT	Percentage of Grain that is contracted	Indeterminate	-3.57	4.87	-17.4
<u>Demographics</u>					
SOY99	GMO soy planted in 1999	Positive	150.86		
CORN99	GMO corn planted in 1999	Positive	42.63	-8.998	7.74
AGE	Age in years.	Negative	-0.6365	4.59	-2.23
INCM1	Income less than \$20,000 per year	Indeterminate	152.34	-368.68	-88
INCM2	Income greater than \$100,00 per year	Indeterminate	-232.74	-212.93	-271.2
EDU	Education Greater than High School	Positive	90.86		
NE	Farm in North East Ohio	Indeterminate	124.71	142.07	443.78
NW	Farm in North West Ohio	Indeterminate	51.43	152.56	132.66
OWNS	Percentage of Farm that is owned	Indeterminate	-86.4	174.48	-70.38
CROPS	Acres of land in crops	Indeterminate	0.1723	0.051	0.09
LVSK	Livestock on farm	Positive	15.95	-13.49	-64.95
<u>Safety</u>					
Risk1	Eating genetically modified food is not highly risky.	Positive	116.61	9.75	97.56
Risk2	Eating genetically modified food is highly risky.	Negative	12.79	439.19	-1233.47
Scnt1	Scientists have studied the long-term risks of eating GM foods.	Positive	21.32	18.85	-6.08
Scnt2	Scientists have not studied the long-term risks of eating GM foods.	Negative	39.22	-7.8	-150.56
Baby1	I would not be hesitant to feed babies with genetically modified food.	Positive	145.29	90.54	-2.32
<u>Environmental</u>					
Herb1	Farmers are not using less herbicide and insecticide by using GM varieties.	Negative	171.45	-1331.4	-571.31
Herb2	Farmers are using less herbicide and insecticide by using GM varieties.	Positive	-78.1	146.3	-285.06
RESIS	Resistant weeds as a concern	Negative	7.79	-109.14	2.81
HERBUSE	Lower herbicide use as a benefit	Positive	153.6		-1152.8
INSCTUSE	Decreased insecticide use as a benefit	Positive		246.996	
<u>Other</u>					
Know1	I do not consider myself knowledgeable about genetic modification.	Indeterminate	-238.7	125.61	-406.93
Know2	I consider myself knowledgeable about genetic modification.	Indeterminate	-57.8	-37.65	-18.93
Worm1	I would not adopt corn resistant to root worms if it becomes available.	Negative	-37.2	-1482.11	-834.74
Worm2	I would adopt corn resistant to root worms if it becomes available.	Positive	36.71	283.37	122.45

* The coefficients bolded indicate that the variable is statistically significant at the 10% or lower

APPENDIX 3. Variable Description, Expected Signs, and Estimated Coefficients in 2000 Share Equations

<u>Variable</u>	<u>Description</u>	<u>Expected Sign</u>	<u>Estimated Coefficients*</u>		
			Soybeans	Bt Corn	Herb-Resistant Corn
<u>Cost and Profitability</u>					
Cost1	Farmers are not realizing cost savings by using GM varieties.	Negative	-0.175	0.7732	0.2239
Cost2	Farmers are realizing cost savings by using GM varieties.	Positive	0.4133	0.3504	-0.0169
PROF	Higher profitability as an advantage	Positive	0.0554		
HERBCOST	Lower herbicide cost as a benefit	Positive	0.1142		0.143
YIELD	Higher yield as a benefit	Positive	0.3247	0.7347	
TILL	Less tillage as a benefit	Positive	0.3147		
INSCTCON	Improved insect control as a benefit	Positive		0.7119	
WEEDCON	Improved weed control as a benefit	Positive			0.4151
<u>Price Risk</u>					
MKT	Ability to market GMO as a concern	Negative	0.0084	0.1482	0.0108
PRE	Premiums for non-GMO's as a concern	Negative	-0.0729	-0.5106	0.355
CNTRCT	Percentage of Grain that is contracted	Indeterminate	0.001	0.0096	-0.0272
<u>Demographics</u>					
SOY99	GMO soy planted in 1999	Positive	0.027		
CORN99	GMO corn planted in 1999	Positive	-0.0554	-0.0771	0.0689
AGE	Age in years.	Negative	0.0024	0.001	-0.0071
INCM1	Income less than \$20,000 per year	Indeterminate	0.2493	-0.4386	-0.0264
INCM2	Income greater than \$100,00 per year	Indeterminate	-0.1599	-0.1905	-0.3271
EDU	Education Greater than High School	Positive	0.0139		
NE	Farm in North East Ohio	Indeterminate	0.0681	0.3915	0.7687
NW	Farm in North West Ohio	Indeterminate	-0.0718	0.4225	0.2988
OWNS	Percentage of Farm that is owned	Indeterminate	-0.1413	0.4009	-0.3572
CROPS	Acres of land in crops	Indeterminate	-0.0000234	-2.13E-05	0.0000595
LVSK	Livestock on farm	Positive	0.0735	0.007	0.0492
<u>Safety</u>					
Risk1	Eating genetically modified food is not highly risky.	Positive	0.1454	0.0292	0.271
Risk2	Eating genetically modified food is highly risky.	Negative	0.1666	0.5848	-2.7106
Scnt1	Scientists have studied the long-term risks of eating GM foods.	Positive	0.0223	0.3601	0.02888
Scnt2	Scientists have not studied the long-term risks of eating GM foods.	Negative	-0.0142	0.2064	-0.2644
Baby1	I would not be hesitant to feed babies with genetically modified food.	Positive	0.1185	-0.1524	-0.2214
<u>Environmental</u>					
Herb1	Farmers are not using less herbicide and insecticide by using GM varieties.	Negative	-0.1061	-2.9229	-1.5481
Herb2	Farmers are using less herbicide and insecticide by using GM varieties.	Positive	-0.1243	0.3411	-0.1883

RESIS	Resistant weeds as a concern	Negative	0.1021	-0.2122	0.0118
HERBUSE	Lower herbicide use as a benefit	Positive	0.2156		-2.3138
INSCTUSE	Decreased insecticide use as a benefit	Positive		0.5004	
<i>Other</i>					
Know1	I do not consider myself knowledgeable about genetic modification.	Indeterminate	-0.1122	0.0609	-0.4248
Know2	I consider myself knowledgeable about genetic modification.	Indeterminate	0.0417	-0.1007	0.056
Worm1	I would not adopt corn resistant to root worms if it becomes available.	Negative	-0.564	-3.2716	-1.9602
Worm2	I would adopt corn resistant to root worms if it becomes available.	Positive	0.0903	0.3973	0.2379

* Coefficients bolded indicate that the variable is statistically significant at the 10% level or lower.