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Role of Information in the Decision to Adopt Genetically Modified Seed

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Abstract:
We examine the role of information in farmers' decisions to adopt GM corn, and find that the set of influential information sources is substantially different in 1997 and 1998. Further, our results suggest that one high quality information source is more influential than the quantity of information.

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A major theme in the technology adoption literature is the role of information in farmers' decisions. In this paper, we examine the role of information in Iowa corn producers' decisions to adopt genetically modified (GM) seed. GM corn hybrids were introduced to a limited extent in 1996. In the first few years, there were two primary innovations: Bt corn and herbicide resistant corn. Bt corn contains an insecticidal protein from the soil bacterium *Bacillius thuringiensis* which confers protection against the European corn borer (ECB). Herbicide resistant corn that has been modified to be resistant to specific herbicides, such as Liberty Link corn, which is resistant to Liberty, and Roundup Ready corn, which is resistant to Roundup. These innovations allow producers either to substitute away from chemicals, in the case of Bt corn, or to use a broader range of chemicals.

We focus on the information usage of early adopters in our survey of Iowa Farm Bureau members, i.e., producers who planted GM corn in 1997 and 1998. According to Rogers (1995), the most important source of information for adopters is other farmers, followed by input suppliers, and local government agencies. However, the information available to early adopters is substantially different from farmers who adopt later. Later adopters can benefit from the experience of the early adopters, but early adopters cannot benefit from others' experience.

The identification of an early adopter is based on the standard deviation from the average time of adoption (Rogers 1995). Given the rapid rate of adoption of GM corn, the early adopter group is limited to those farmers who adopted GM corn in 1996 and 1997, and perhaps 1998. The USDA estimates that GM corn usage in the United States increased from 4.4% of corn acreage in 1996 to 11.9% in 1997, and 28.1% in 1998. GM corn usage peaked in 1999 at 33.9%. In 2000 and 2001, GM corn acreage fell to 24% and 25%, respectively, perhaps due in part to the controversy in Europe and Japan about food products containing GM ingredients (Fernandez-Cornejo, Daberkow and McBride 2002). In our sample of Iowa Farm Bureau members, the adoption of GM corn was even more rapid than in the U.S. as a whole. In 1997, 27% planted GM corn, and the proportion increased to 57% in 1998.

In particular, we examine which information sources are the most influential in the adoption decision. In addition to the total number of information sources used by the producers, we also include the producers' assessments of the importance of the information source to their planting decisions, and their assessment of the reliability of the sources' information. For the 1998 planting decision, we include the producers' 1997 planting decisions. Producer's own experience with GM crops, if any, will provide the most relevant and reliable information (Marra, Hubbell and Carlson 2000). We find that the influential information sources differed substantially in 1997 and 1998. In addition, we find that adopters were most likely to rely on a small number of information sources that they consider reliable.

1. Related literature

The sociology literature has demonstrated that different sources of information are influential at different stages of the individual farmer's adoption decision process (Rogers 1995, Korsching and Hoban 1990). Mass media plays an important role in making the farmer aware of the innovation. In making the adoption decision, farmers rely more on information sources that can provide technical assistance and detailed knowledge.

Economists have found that farmers who use information sources which offer technical assistance or more detailed information are most likely adopt new technologies. Lichtenberg and Berlind (2002) examine whether farmer's pesticide decisions are influenced by the source of scouting information, comparing scouting by farmers, chemical dealers and independent crop consultants. They find that soybean growers who use extension trained scouts used fewer pesticides than when they scout their own fields or the chemical dealer scouts. However, they find no relationship between the source of scouting information and pesticide demand for corn, alfalfa and small grains. Daberkow and McBride (2001) find that farmers' decisions to adopt precision farming techniques are influenced by private sector information sources, primarily commercial crop consultants, but also input suppliers. Wozniak (1987) found that frequency of contact with extension-supplied information had a significant and positive effect on the probability that an Iowa farmer would be an early adopter of a cattle feed supplement (monensin sodium).

Economists and sociologists have identified a number of stylized facts about early adopters. First, farmers face a fixed cost when adopting a new technology, derived from gathering information and learning about the technology (Lindner 1983). In this case, early adopters will most likely be farmers who face a lower cost of acquiring information about the new technology, such as farmers with larger farms and more schooling. Fernandez-Cornejo et al. (2002) found that larger farms were more likely to have adopted GM corn.

Second, more experienced farmers and farmers with more schooling are expected to have a better understanding of whether a new technology will be profitable, and thus are more likely to be early adopters. However, GM crops tend to require less management skill, which may offset this stylized fact. For example, Bt corn virtually eliminates the need for chemical insecticides to abate damage from ECB. In order to use chemical insecticides as a cost effective control measure, the farmer must be actively scouting the corn fields and measuring the number of ECB larvae per plant. Hence, less experienced farmers and farmers with less schooling may realize greater benefits from GM crops than farmers who are skilled at using conventional methods of controlling pests.

Third, farmers who believe the new technology can provide a relatively large increase in profits will be more likely to adopt. In the case of GM crops, farmers who view yield damage from either weeds or ECB as a serious problem will be more likely to adopt, or at least experiment with the crop. Farmers who believe GM crops provide either a more effective means of controlling ECB, or allow the farmer to use more effective herbicides, will certainly be more likely to adopt. In addition, younger farmers who have a longer time horizon in which they can use the information they gain by adopting GM crops are more likely to be early adopters.

Finally, farmers who actively acquire information will be more likely to adopt early (Jensen 1982, Feder and Slade 1984, McCardle 1985). The usefulness of the information will depend on both the quantity and the quality of the information. In addition, farmers are more likely to be persuaded to adopt a new technology by more credible sources of information, where credibility depends both on the information source's expertise and motivation (Rogers 1995). For example, farmers can acquire "more" information by: using a large number of information sources and using information sources the farmer describes as very reliable.

2. Empirical model of role of information in adoption decisions

We will examine farmers' decisions to adopt Bt corn and herbicide resistant corn (both Roundup Ready and Liberty Link) in 1997 and 1998. While GM corn was first introduced in 1996, it became widely available in 1997.[1] The dependent variable is the share of acreage (between 0 and 1) planted to GM corn. We use a two-limit tobit model to estimate both the decision to adopt GM corn and the intensity of adoption. The two-limit Tobit model is particularly suited to cases where the technology is divisible, and when farmers vary in their intensity of adoption (Feder, Just and Zilberman 1985, Fernandez-Cornejo et al. 2002). The coefficients in a two-limit tobit model capture the total effect of a change in the explanatory variable on the number of adopters and the extent of adoption (Gould, Saupe and Klemme 1989).

In order to examine the role of information in farmers' decisions to adopt new seeds, we will test a general adoption model that includes the characteristics of the farm and farmer that determine the expected profitability of the seed, the farmer's ability to utilize information, and the information sources used by the farmer.

Several papers have pointed to a sample selection bias inherent in survey data regarding the adoption of a new technology; only farmers who are aware of a new technology will decide whether or not to adopt it. This group of farmers is likely to be a non-random subset (Saha, Love and Schwart 1994, Daberkow and McBride 2001). However, we believe this self-selection bias is relatively small

[1] In focus groups with Iowa corn-soybean farmers, most of the participants commented that GM corn was not for sale in their area in 1996.

in our case for the three following reasons: first, we examine adoption in 1997, the second year GM crops were available, second, there was substantial publicity surrounding the introduction of GM crops, and third, our sample was restricted to Iowa Farm Bureau members who operate farms of 100 acres or more. This group tends to be more progressive than the average Iowa farmer.[2]

3. Data and Estimation

UC-Davis collected data with the cooperation of the Iowa Farm Bureau Federation on producers' planting decisions, production practices, farm characteristics, operator characteristics and attitudes towards risk and biotechnology. Mail surveys were sent to 1,000 Iowa Farm Bureau members who grow corn and plant at least 100 acres of row crop. We restricted the sample to farms of 100 acres of row crop or more in order to focus on the farms that produce the majority of the corn in Iowa. Farms of 100 acres or more account for 58.6% of Iowa farms and produced 90.2% of the 1997 corn crop (USDA 1999). The first wave of the survey was mailed February 9, 2000 and a second copy was sent to non-respondents on March 1, 2000. Our gross response rate was 43%. After excluding the undeliverable surveys, we obtained 389 usable responses for a usable response rate of 38.9%.[3]

In addition to questions regarding the standard set of variables used in adoption studies such as the characteristics of the farm and farmer that determine the expected profitability of the seed, the survey included questions on information sources. Producers were asked to rank the importance and reliability of the following information sources: seed dealer, chemical supplier, pest control advisor, extension agent, agricultural publications, farm shows and fairs, other farmers, internet and Iowa State University (ISU) test yields. Since farmers form beliefs about the reliability and importance of information sources over time, we believe that, with the exception of the internet, we can use farmers' assessments of information sources in 2000 to explain 1997 and 1998 adoption decisions. Since the availability of information on the internet changed substantially between 1997

[2] The rapid adoption of GM crops provides further support for our assumption that all farmers were aware of GM crops in 1997.

[3] Undeliverable means that the farmers were either retired, renting out their land, or deceased.

and 2000, we cannot consider the internet as a viable information source in 1997. Even in 2000, the internet was considered an unimportant and unreliable source of information. However, whether or not the farmer uses the internet in 2000 is an indication of the farmer's willingness to innovate.

The farmer's rating of the importance of the information source will depend in large part on the farmer's assessment of the reliability of the information source. In order to minimize multicollinearity, given the strong positive correlation between the information and reliability ratings, we construct two indices to capture the overall influence of an information source in the farmer's planting decisions. The first index is composed of the the *product* of the farmer's description of how important the information source is to their planting decisions and their evaluation of the relative reliability of the information source. The second index is composed of the *sum* of the importance and relative reliability ratings. Since we have no theoretical reason to choose a particular functional form for the relationship between importance and reliability, we examine both indices to provide a comparison. Both indices suggest that the information is most influential if it is considered relatively important and relatively reliable. Some farmers rate an information source important, yet unreliable, and we expect this information source to be less influential. Very few of the farmers rate a source reliable and unimportant, though these sources would also have a low rating. For both indices, the information source is given a score of zero if the farmer does not use a specific information source. One major drawback of the multiplicative index is that if the importance rating or reliability rating are missing, the score is also zero, leading to a relatively large number of zero scores. For the sum index, if one of the ratings is missing, then the information source will have a low, positive score.

We estimate three tobit models for farmer adoption in 1997, each with different information source variables:[4]

$$y_t^* = \beta' x_t + \epsilon_t \tag{1}$$

y_t^* is a latent variable representing the share of GM corn acreage which is unobserved for values smaller than 0 or larger than 1, i.e.:

$$y_t^* = \begin{cases} 0 & \text{if} \quad y_t^* \leq 0 \\ y_t^* & \text{if} \quad 0 \geq y_t^* \leq 1 \\ 1 & \text{if} \quad y_t^* \geq 1 \end{cases} \tag{2}$$

x_t is a vector of independent variables which explain adoption, β is a vector of unknown parameters, and ϵ_t is a disturbance term assumed to be independently and normally distributed with zero mean and constant variance σ, and $t = 1...n$ where n is the number of observations.

The baseline model includes the number of information sources. The second includes the farmers rating of the information sources where the index is the product of the importance and reliability ratings. For the internet as an information source, we include a dummy variable for internet usage. The third model includes a different index of the information sources that is the sum of the importance and reliability ratings and for the internet, we again include a dummy if the farmer used the internet.

We also estimate the three tobit models for farmer adoption in 1998, where we examine the three different sets of information source variables, including the farmer's 1997 planting decisions. Farmers who have planted GM corn in 1997 have gathered additional high quality information that will certainly influence their 1998 planting decisions.

[4] We used STATA 7.0 to estimate the two-limit tobit model.

4. Results and Discussion

In our empirical analysis, we begin by examining summary statistics that describe the farmer's information use, and ranking of the importance and reliability of the information sources. Subsequently, we present the results for the three tobit models for farmer adoption in 1997 and 1998. Finally, we compare the 1997 and 1998 adoption decisions.

4.1. **Farmer information use:** Over 90 percent of the farmers in our sample use information from seed dealers, chemical suppliers, other farmers, and agricultural publications. About four-fifths of the farmers use information from the Iowa State University yield trials. Three-quarters of the farmers get information from farm shows and fairs. About two-thirds get information from a pest control advisor. Just under two-thirds use Cooperative Extension as a source of information. Less than half of the farmers in the sample use the internet. See Table 1.

Table 1: Percent of farmers who use each information source

Information Source	Percent who use
Seed dealer	98.4
Chemical supplier	95.4
Other farmers	93.7
Agricultural publications	92.1
Iowa State test yields	82.0
Farm shows and fairs	75.6
Pest control advisor	64.3
Extension agent	60.8
Internet	41.4

Farmers' ranking of the importance and reliability of each source of information:

In order to identify which sources of information farmers view as important and reliable, we examine the unweighted mean of the farmers' rating of each source of information. To account for heterogeneity in farmers' beliefs about the importance and reliability of the information sources, we also examine the mean of the farmers' rating of each source of information, weighted by the mean of the farmer's rating of the importance and reliability of all information sources. For the weighted mean, a value above 1 indicates that farmers' believe that source of information is above average in importance or reliability, and a mean below 1 indicates that source of information is below average in importance or reliability. The three most frequently used sources of information (seed dealers, chemical dealers and other farmers) are also ranked the most important sources of information by both the weighted and unweighted mean, and the most reliable sources of information by the weighted mean.

Seed dealers are considered the most important and most reliable source of information by all rankings (Tables 2 and 3). Chemical suppliers are the second most important source of information, and they are considered the second most reliable based on the weighted mean and third most reliable based on the unweighted mean.

Other farmers, Iowa State test yields, and pest control advisors are about the same level of importance based on the unweighted mean, but the weighted mean provides a clear ranking with other farmers as the third most important source of information, the Iowa State test yields are fifth, and pest control advisors are ranked seventh. The Iowa State test yields and other farmers are ranked high in reliability, though their relative ranking switches for the unweighted and weighted means. Based on the unweighted mean, the Iowa State test yields are the second most reliable with other farmers as the fourth most reliable. Based on the weighted mean other farmers are the third most reliable with the Iowa State test yields as the fourth most reliable. Pest control advisors rank sixth most reliable based on the unweighted mean and seventh based on the weighted mean.

Agricultural publications are ranked higher in importance and reliability based on the weighted mean relative to the unweighted mean. They are ranked fourth most important and fourth most reliable by the weighted mean, and sixth most important and seventh most reliable by the unweighted mean.

Farm shows and fairs, extension agents, and the internet rank relatively low in importance and reliability. Farm shows and fairs are ranked higher by the weighted mean at sixth most important and sixth most reliable, compared the unweighted mean at eighth in importance and reliability. Extension agents rank higher by the unweighted mean at seventh most important and fifth most reliable, compared to the weighted mean at eighth in importance and reliability. The internet is considered the least important and least reliable source of information by all rankings.

Table 2: Unweighted and weighted mean of farmers' rank of the importance of the information source for their planting decision. 4=very important, 3=somewhat important, 2=not at all important.

Information Source	Mean	Mean weighted by each farmer's belief about importance of information (range [.5, 2])
Seed dealer	3.49	1.13
Chemical supplier	3.37	1.05
Other farmers	3.08	0.95
Iowa State test yields	3.04	0.82
Pest control advisor	3.02	0.63
Agricultural publications	2.93	0.89
Extension agent	2.84	0.57
Farm shows and fairs	2.66	0.66
Internet	2.63	0.37

Table 3: Unweighted and weighted mean of farmers' rank of the reliability of this source for seed corn information. 3=very reliable, 2=somewhat reliable, 1=not at all reliable.

Information Source	Mean	Mean weighted by each farmer's belief about reliability of information (range [.33,3])
Seed dealer	2.52	1.12
Iowa State test yields	2.37	0.87
Chemical supplier	2.35	0.99
Other farmers	2.31	0.98
Extension	2.27	0.61
Pest control advisor	2.12	0.62
Agricultural publications	2.11	0.87
Farm shows and fairs	1.93	0.64
Internet	1.90	0.36

4.2. **1997 Adoption decision.** In the three tobit regressions for the adoption of GM corn in 1997, several variables are consistently significant with the predicted sign. First, larger farms as measured by their 1999 Gross Farm Income are significantly more likely (at the 99% level) to adopt GM corn. Second, farmers who are more concerned about yield damage from ECB are significantly more likely (at the 99% level) to adopt GM corn. Farmers who scout their fields to estimate the ECB populations are significantly more likely (at the 95% or higher level) to adopt GM corn.

Farmers who use either reduced tillage practices or no tillage, and are therefore more dependent on herbicides to control weeds, are significantly more likely (at the 95% level) to adopt GM corn. For the regressions that include the farmers' rating of the information sources, their concern about weed damage and the number of weed control practices are jointly, weakly significant at the 90% level according to F-tests.[5] The farmers' years of schooling negatively and significantly affect the planting of GM corn in 1997. The farmers' age and years of experience are also negatively correlated with the share of GM corn. Overall, F-tests indicate that the human capital variables of age, experience and years of schooling are jointly significant at the 95% level or higher.[6] The fact that younger, less experienced farmers with fewer years of schooling are significantly more likely to plant GM corn than older, more experienced farmers with more schooling supports the perception that GM crops require less management skill.

Contrary to our prediction that farmers who have more information are more likely to be early adopters, in the regression without information ratings, there is a negative, but not significant relationship between adoption and the number of information sources used by the farmer. However, once the ratings of the information sources are included, the relationship between the number of information sources and adoption reverses, and farmers who use more information sources are more likely to be early adopters. This relationship is significant at the 95% level in Table 6.

Table 5 and 6 examine the role of specific information sources in farmers' adoption decision, using two different rating indices. In Table 5, the information source rating is composed of the product of the farmer's importance rating and the relative reliability of the information source. In Table 6, the information source rating is composed of the sum of importance and relative reliability. Both sets of information ratings are jointly significant at the 99% level and the signs of the coefficients for both rating indices are consistent.[7]

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[5] Table 4: $F(2, 269) = 0.78$, Prob $> F = 0.45$; Table 5: $F(2, 260) = 2.73$, Prob $> F = 0.06$; Table 6: $F(2, 260) = 2.67$,Prob $> F = 0.07$

[6] Table 4: $F(3, 269) = 2.78$, Prob $> F = 0.04$; Table 5: $F(3, 260) = 3.08$, Prob $> F = 0.01$; Table 6: $F(3, 260) = 3.23$, Prob $> F = 0.02$

For both sets of information importance and reliability indices, farmers who give a high rating based on either index to their seed dealer were significantly more likely to adopt in 1997. Farmers who give a high rating to agricultural publications were also more likely to have adopted GM corn in 1997. Farmers who give a low rating to their chemical dealer were significantly more likely to adopt in 1997. In addition, farmers who give a low rating to their pest control advisor were more likely to adopt in 1997. Both the chemical dealer and the pest control advisor focus on the use of chemicals to control pests, and GM crops are a substitute for chemicals. Farmers who do not trust their chemical suppliers and advisors, will be more likely to take steps to reduce their dependence on chemicals.

Farmers who rely on information sources that could not provide much information about GM crops in 1997, were either less likely to adopt or uninfluenced by the information. Farmers who give a high rating to other farmers were also less likely to adopt GM corn in 1997, which is unsurprising since very few farmers will have planted GM crops the previous year. Farmers who give a high rating to information from farm shows and fairs were significantly less likely to adopt GM corn in 1997. Most likely the farm shows provided very little information on GM crops when the farmers were making their 1997 planting decisions. Information from extension agents and the ISU yield trials did not influence the farmers' 1997 adoption decision, which is likely due to the fact that GM crops were developed and marketed by the private sector. The public sector could not offer much relevant information about GM crops in the second year of availability. In the case of the ISU yield trials, the seed companies could only enter seeds that are commercially available.[8] Since the availability of GM seeds was limited in 1996, there would be a limited number of GM seeds in the trials.

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[7] Table 5: $F(8, 260) = 3.55$, $Prob > F = 0.0006$; Table 6: $F(8, 260) = 3.26$, $Prob > F = 0.0015$

[8] The eligibility requirements for entering a seed into the ISU trials were changed in 2001 to allow companies to enter seeds that are in advanced trials.

Farmers' usage of the internet in 2000 is significantly, negatively correlated with the share of GM corn in 1997. This relationship contradicts our hypothesis that, as an indicator of progressiveness, internet use would be correlated with adoption.

Table 4: Tobit estimates of 1997 GM corn adoption. [a]

	Share GM corn 1997
Total Acres (100s)	-0.015
	(1.11)
1999 GFI ($1000s)	0.0015***
	(3.53)
Value of farmland ($100,000s)	0.011
	(1.17)
No. livestock operations	-0.054
	(1.21)
Years of School	-0.016
	(0.60)
Age	-0.009
	(0.88)
Experience	-0.005
	(0.53)
Concern yield damage from ECB	0.195***
	(3.30)
Scouts for ECB	0.287**
	(2.16)
Concern yield damage from weeds	0.022
	(0.42)
Number of weed control practices	0.022
	(0.42)
Share acres no or reduced till	0.005**
	(1.99)
No. info sources	-0.045
	(1.54)
Constant	-0.325
	(0.59)
Observations	282
Pseudo R^2	0.21

[a] Absolute value of t statistics in parentheses;*** significant at 99%; ** significant at 95%;* significant at 90%

Table 5: Tobit estimates of 1997 GM corn adoption. Info rating: importance times relative reliability. [a]

	Share GM corn 1997
Total Acres (100s)	-0.022
	(1.68)
1999 GFI ($1000s)	0.001***
	(3.80)
Value of farmland ($100,000s)	0.008
	(0.94)
No. livestock operations	-0.075*
	(1.73)
Years of School	-0.056**
	(2.06)
Age	-0.008
	(0.86)
Experience	-0.007
	(0.79)
Concern yield damage from ECB	0.250***
	(4.25)
Scouts for ECB	0.298**
	(2.33)
Concern yield damage from weeds	0.076
	(1.45)
Number of weed control practices	0.063
	(1.63)
Share acres no or reduced till	0.005**
	(2.46)
No. info sources	0.069
	(1.57)
Seed dealer rating	0.107**
	(2.29)
Chemical dealer rating	-0.172***
	(3.47)
Pest control advisor rating	-0.108**
	(2.49)
Extension agent rating	-0.015
	(0.34)
Ag publication rating	0.099
	(1.56)
Farm show and fair rating	-0.164***
	(2.64)
Other farmer rating	-0.128***
	(2.79)
ISU test yield rating	-0.028
	(0.80)
Internet usage	-0.241**
	(2.04)
Constant	-0.185
	(0.32)
Observations	282
Pseudo R^2	0.32

[a] Absolute value of t statistics in parentheses;*** significant at 99%; ** significant at 95%;* significant at 90%

Table 6: Tobit estimates of 1997 GM corn adoption. Info rating: sum of importance and relative reliability. [a]

	Share GM corn 1997
Total Acres (100s)	-0.018
	(1.36)
1999 GFI ($1000s)	0.0014***
	(3.65)
Value of farmland ($100,000s)	0.007
	(0.84)
No. livestock operations	-0.070
	(1.62)
Years of School	-0.054**
	(2.00)
Age	-0.006
	(0.70)
Experience	-0.007
	(0.76)
Concern yield damage from ECB	0.240***
	(4.11)
Scouts for ECB	0.305**
	(2.35)
Concern yield damage from weeds	0.086
	(1.59)
Number of weed control practices	0.058
	(1.47)
Share acres no or reduced till	0.005**
	(2.28)
No. info sources	0.109**
	(2.01)
Seed dealer rating	0.197***
	(2.61)
Chemical dealer rating	-0.250**
	(3.73)
Pest control advisor rating	-0.0967**
	(2.27)
Extension agent rating	-0.010
	(0.22)
Ag publication rating	0.079
	(1.13)
Farm show and fair rating	-0.157***
	(2.68)
Other farmer rating	-0.110**
	(1.96)
ISU test yield rating	-0.027
	(0.63)
Internet use	-0.262**
	(2.12)
Constant	-0.306
	(0.49)
Observations	282
Pseudo R^2	0.30

[a] Absolute value of t statistics in parentheses;*** significant at 99%; ** significant at 95%;* significant at 90%

4.3. **1998 Adoption decision.** Prior experience with GM corn in 1997, which generates the most useful information, is by far the most influential variable in explaining farmers' 1998 adoption and planting decisions. In 1998, total rowcrop acreage was positively and significantly (at the 95% level) related to the share of GM corn. In 1998, age had a significant (at the 95% level), negative relationship with the share of GM corn. Again, the human capital variables which include age, experience and years of schooling were jointly significant at the 90% level.[9] However, now there is a positive relationship between adoption and years of schooling and experience.

As in 1997, the farmer's concern about yield damage from ECB is positively and significantly (at the 99% level) correlated with the share of GM corn. The farmer's scouting activities are no longer significant to the farmer's planting decision, which suggests that the farmers who are the most active in abating damage from ECB were also more likely to be the very early adopters. Tillage practices, farmer concern about weed damage and the number of weed control practices are no longer significant to the farmers' planting decisions, providing further evidence that the most active managers adopted in 1996 or 1997.

The number of information sources used by the farmers is negatively related to the adoption of GM corn, and unlike in 1997, continues to be weakly significant after the information indices are included. This relationship suggests that the non-adopter group may be more risk averse than adopters, and require more information to reduce the uncertainty related to adopting a new technology.

Overall, neither set of information indices is significant to the farmers' planting decisions. For both indices, only the ISU yield trials influence adoption. Farmers who used the ISU yield trial information, were significantly more likely (at the 95% level) to plant GM corn in 1998. The ISU yield trial information is considered relatively reliable and important, and we would expect farmers

[9] Table 7: $F(3, 265) = 2.26$, $Prob > F = 0.08$; Table 8: $F(3, 265) = 2.62$, $Prob > F = 0.05$; Table 9: $F(3, 265) = 2.60$, $Prob > F = 0.05$

to be influenced by this information (see Tables 2 and 3). In 1998 the yield trials could have included a larger number of GM seeds than in 1997, and thus provided more useful information.

Table 7: Tobit estimates of 1998 GM corn adoption. [a]

	Share GM corn 1998
Share GM corn 1997	1.262***
	(9.71)
Total Acres (100s)	0.013**
	(2.02)
1999 GFI ($1000s)	-0.0001
	(0.92)
Value of farmland ($100,000s)	0.002
	(0.48)
No. livestock operations	-0.018
	(0.89)
Years of School	0.007
	(0.62)
Age	-0.009**
	(2.25)
Experience	0.005
	(1.42)
Concern yield damage from ECB	0.082***
	(3.10)
Scouts for ECB	-0.003
	(0.06)
Concern yield damage from weeds	-0.009
	(0.43)
Number of weed control practices	0.023
	(1.28)
Share acres no or reduced till	0.002
	(1.54)
No. info sources	-0.032**
	(2.47)
Constant	0.218
	(0.93)
Observations	279
Pseudo R^2	0.40

[a] Absolute value of t statistics in parentheses;*** significant at 99%; ** significant at 95%;* significant at 90%

Table 8: Tobit estimates of 1998 GM corn adoption. Info rating: importance times relative reliability. [a]

	Share GM corn 1998
Share GM corn 1997	1.279***
	(9.48)
Total Acres ($100s)	0.012*
	(1.76)
1999 GFI ($1000s)	-0.0001
	(1.01)
Value of farmland ($100,000s)	0.003
	(0.67)
No. livestock operations	-0.015
	(0.76)
Years of School	0.011
	(0.94)
Age	-0.009**
	(2.28)
Experience	0.005
	(1.34)
Concern yield damage from ECB	0.071***
	(2.64)
Scouts for ECB	0.0008
	(0.01)
Concern yield damage from weeds	-0.014
	(0.61)
Number of weed control practices	0.023
	(1.31)
Share acres no or reduced till	0.002
	(1.56)
No. info sources	-0.043**
	(1.96)
Seed dealer rating	0.0004
	(0.02)
Chemical dealer rating	0.022
	(1.04)
Pest control advisor rating	-0.00009
	(0.00)
Extension agent rating	-0.025
	(1.08)
Ag publication rating	0.002
	(0.09)
Farm show and fair rating	0.035
	(1.16)
Other farmer rating	-0.021
	(0.96)
ISU test yield rating	0.044**
	(2.35)
Internet use	-0.004
	(0.08)
Constant	0.134
	(0.53)
Observations	279
Pseudo R^2	0.42

[a] Absolute value of t statistics in parentheses;*** significant at 99%; ** significant at 95%;* significant at 90%

Table 9: Tobit estimates of 1998 GM corn adoption. Info rating: sum of importance and relative reliability. [a]

	Share GM corn 1998
Share GM corn 1997	1.262***
	(9.67)
Total Acres (100s)	0.012*
	(1.86)
1999 GFI ($1000s)	-0.0002
	(1.16)
Value of farmland ($100,000s)	0.002
	(0.59)
No. livestock operations	-0.013
	(0.68)
Years of School	0.012
	(1.01)
Age	-0.009**
	(2.34)
Experience	0.006
	(1.46)
Concern yield damage from ECB	0.073***
	(2.73)
Scouts for ECB	0.0006
	(0.01)
Concern yield damage from weeds	-0.015
	(0.66)
Number of weed control practices	0.021
	(1.21)
Share acres no or reduced till	0.001
	(1.50)
No. info sources	-0.046*
	(1.80)
Seed dealer rating	-0.007
	(0.23)
Chemical dealer rating	0.024
	(0.84)
Pest control advisor rating	-0.004
	(0.20)
Extension agent rating	-0.035
	(1.55)
Ag publication rating	0.031
	(0.98)
Farm show and fair rating	0.024
	(0.85)
Other farmer rating	-0.028
	(1.06)
ISU test yield rating	0.052**
	(2.40)
Internet use	0.002
	(0.04)
Constant	0.110
	(0.42)
Observations	279
Pseudo R^2	0.43

[a] Absolute value of t statistics in parentheses;*** significant at 99%; ** significant at 95%;* significant at 90%

4.4. **Comparison of 1997 and 1998 adoption decisions:** The farmers who adopted GM corn in 1997 fit the stylized facts of early adopters, while the farmers who planted GM corn in 1998 are closer to the average farmer in our sample.

Farmer concern about yield damage from ECB, and the number of information sources were the only variables that were significant in both 1997 and 1998. Bt corn comprises the majority of the GM corn adopted, and farmers who believe that ECB damage is costly will be more likely to believe that Bt corn is profitable relative to chemical insecticides. In both 1997 and 1998, adopters tended to use fewer information sources than non-adopters. We find that the influential set of information sources is substantially different in 1997 and 1998. Consistent with Korsching and Hoban (1990), we find that only a couple of information sources positively influence adoption in 1997, including the seed dealer and, to a less extent, agricultural publications. Despite a high overall information and reliability score for information from the chemical dealer, the farmers who adopted GM corn were either less reliant on their chemical dealer for advice, or the farmers who relied most on the information from their chemical dealer were the least likely to adopt. Adopters also consider a large number of other information sources unimportant and unreliable; in particular, the pest control advisor, farm shows and fairs, and other farmers receive a low rating. Internet usage in 2000 was negatively correlated with adoption of GM crops. In contrast, in 1998, only the Iowa State yield trial information was influential. Overall, these findings suggest that new adopters in 1997 are most likely to rely primarily on their seed dealer, which was the most influential source of information.

Both farm size and human capital variables are significant in 1997 and 1998. Of the two measures of farm size, 1999 gross farm income is positive and significant in the 1997 regression and total acres of row crops is also positive and significant in the 1998 regression. Farms with a larger gross farm income tend not only to be larger, but also more diversified across livestock and row crop activities. Farm diversification which allows the farmer to spread the risk associated with planting a new technology, may be particularly important early in the adoption process. Larger farms, in acreage terms, may be more willing to adopt a GM corn relatively early for several reasons: GM corn requires less management effort and management effort is more likely to be a constraint on larger farms and the cost of testing a new crop is a fixed cost which is relatively lower for larger farms, while the benefits if the crop is profitable are relatively higher.

Of the three human capital variables (experience, years of schooling, and age), years of schooling is negative and significant in 1997 and age is negative and significant in 1998. While we expect that years of schooling would positively influence adoption of most technologies, GM corn requires less management effort, and may offer larger gains to farmers with fewer years of schooling.

5. Concluding Remarks

We examine the role of information in farmers' 1997 and 1998 decisions to adopt GM corn, using a two-limit tobit model. We find that adopters in 1997 fit the stylized facts of early adopters. In contrast, the influential variables in 1998 suggest that, other than concern about yield damage from European Corn borer, we can no longer distinguish between the average farmer and farmers who plant GM corn. In particular, a larger number of information sources was influential in 1997 than 1998, which suggests that access to information may have been a constraint in 1997, relative to 1998. Farmers' use of information sources in 1997 suggests that the quality of the information source matters more than the total number of information sources.

We use two different indices to capture the value of the information source to the farmer's planting decisions. We find that the coefficients on the information sources are consistent across the indices. In future work, we plan to investigate whether instrumental variables improve upon these information indices.

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