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Effects of the GM Controversy on Iowa Corn-Soybean Farmers' Acreage Allocation Decisions

Corinne Alexander, Jorge Fernandez-Cornejo, and Rachael E. Goodhue

Prior to the 2000 planting season, some industry observers predicted acreage of genetically modified crops would decline dramatically. However, actual 2000 plantings presented a puzzle. Farmers reduced their acreage of genetically modified corn, but concurrently increased their acreage of genetically modified soybeans. We demonstrate that it may be theoretically optimal for risk-averse farmers to reduce their corn acreage but not their soybean acreage. However, past experience, attitudes, and farm size explained planting decisions to a larger degree than did risk preferences.

Key words: expected utility, genetically modified crops, two-limit tobit model

Introduction

The introduction of genetically modified (GM) crops in 1996 was heralded as a new era of agriculture; farmers would benefit from lower production costs, higher yields, and reduced pesticide use. From the beginning, Europe and Japan expressed misgivings about food that had been genetically manipulated, and refused to import transgenic grain. The European and Japanese consumer controversy over GM crops intensified in late 1999 and early 2000. Anticipating the possibility this negative reaction would spark consumer concerns in the United States, several American companies, including Gerber, Frito-Lay, and Heinz, announced they would discontinue use of GM ingredients in their products. Consequently, agricultural producers entering the 2000 crop year faced increased uncertainty regarding the demand for these crops.

Prior to the 2000 planting season, some industry observers predicted GM acreage would decline dramatically. However, actual 2000 plantings presented a puzzle. Farmers reduced their acreage in GM corn, but concurrently increased their acreage in GM soybeans. Our objective is to analyze the determinants of spring 2000 planting decisions, and evaluate the importance of demand uncertainty for GM crops as a decision factor.

Corinne Alexander is an assistant professor in the Department of Agricultural Economics, Purdue University; Jorge Fernandez-Cornejo is an economist with the Economic Research Service, USDA; and Rachael E. Goodhue is an assistant professor in the Department of Agricultural and Resource Economics, University of California at Davis, and a member of the Giannini Foundation of Agricultural Economics. The views expressed are those of the authors and do not necessarily correspond to the views or policies of the U.S. Department of Agriculture.

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We model the demand uncertainty as an uncertain price penalty for GM crops. A theoretical model of the acreage allocation decision for a risk-averse producer is paired with producers' assessments of the relative production risks and returns of GM and conventional crops. These assessments were elicited using focus groups. Testable hypotheses are obtained regarding the effects of the GM controversy, and then are tested using data from a spring 2000 survey of Iowa producers.

Theoretical Model

A producer's acreage allocation decision is modeled using expected utility maximization for a risk-averse producer choosing between a GM and a conventional variety. The producer faces yield risks for GM and conventional products. Due to the controversy, the producer faces a further risk for the GM crop in addition to price risk. In comparing the GM and conventional varieties, we focus on the additional risk associated with the GM alternative, since both the GM and conventional crops face the same underlying price risk associated with commodity crops. In order to emphasize the GM-conventional variety choice, the allocation decision is examined within a specific commodity rather than across commodities. Including commodity price risk responses and the cross-commodity acreage allocation decision would complicate the analysis substantially without providing additional insight into the questions we emphasize.

The decision to model risk-averse producers is based on findings of previous economic research as well as producer comments elicited through focus group discussions. Several empirical studies have established that producer risk aversion is an important factor in acreage allocation decisions using producer-level data. Results of a study conducted by Marra and Carlson suggest the intensity of adoption could be explained by differences in farmer attitudes toward risk and the covariance of enterprise returns. Saha, Shumway, and Talpaz jointly estimated production function and utility function parameters and determined that Kansas wheat farmers exhibited risk-averse preferences. In reviewing the agricultural economics literature on risk aversion, Moschini and Hennessy note that producers typically exhibit some degree of risk aversion, and most frequently decreasing absolute risk aversion, and increasing relative risk aversion. More generally, Binswanger used experimental methods to identify individuals' risk preferences, and found his subjects' preferences were consistent with decreasing absolute risk aversion.

Three focus groups were conducted in cooperation with the Iowa Farm Bureau Federation.[1] During the focus group discussions, producers' concerns were elicited about marketing GM crops, as well as their evaluation of the production characteristics. Price risk was the common factor across their three primary concerns, even though we did not explicitly ask about the possibility of a price discount.[2] First, producers were concerned there would be an actual price penalty on GM crops. Second, they expressed concern that elevators would not accept GM crops for the first few months following the harvest. Farmers with operating loans may incur substantial interest payments if they wait to

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[1] For each county, the Iowa Farm Bureau Federation county agent provided us a list of names of progressive farmers who tended to be informed about technological breakthroughs and informed about current events. We then recruited the farmers from this list who had experience with GM crops. Three focus group sessions were conducted—two groups in Mason City in north-central Iowa, and one in Albia in south-central Iowa, with a total of 21 participants.

[2] Of course, the effect of this risk on returns and utility depends on government programs which may protect participants from price variance. We are indebted to Dan Sumner for this observation.

sell their crop, resulting in an effective price discount. Third, they were concerned that elevators would *never* accept GM crops, although most focus group participants thought this scenario was very unlikely to occur. As noted by some participants, an additional indirect price discount would result if producers are required to segregate their GM crops.

Of course, producer risk aversion is not the only potential explanation for producer behavior. Various types of heterogeneity could be used to explain producers' acreage allocation decisions regarding GM varieties. For instance, corn planted early in the season and corn in southern Iowa are more susceptible to damage from the European corn borer (ECB) than corn planted mid-season and corn in northern Iowa, respectively. Alternatively, producers vary in their ability to grow crops, and some GM crops are easier to produce than conventional varieties. Land heterogeneity could explain acreage allocations based on average yield differences due to soil quality or susceptibility to weed problems. Variables are included in our empirical model to address these and other potential explanations for acreage allocation decisions. Due to the nature of producer concerns, however, specific focus is on price and production risk in our theoretical model.

A general model of a producer's decision is used to allocate acreage among conventional varieties and GM varieties for any crop, based on the model of a risk-averse firm developed by Sandmo, and developed for acreage allocation decisions by Just and Zilberman (1983, 1984). The model closely follows the logic of Just and Zilberman (1983), although our comparative statics focus on different variables, so our derivations are not presented here. P is defined as the output price, P_1 as the land price, and the crop yields as $Y_i \sim (\bar{Y}_i, \sigma^2_{Y_i})$, where $i = c$ for the conventional crop, and $i = gm$ for the GM crop. Pest control costs are separated from other production costs because GM input traits affect the producer's pest control options. Certain production costs are denoted by C_i, pest control costs are denoted by $Z_i \sim (\bar{Z}_i, \sigma^2_{Z_i})$, and acreage is denoted by A_i. An uncertain output price penalty is included for GM crops, $d \sim (\bar{d}, \sigma^2_d)$, $0 \geq \bar{d} \geq P$, to illustrate one potential impact of the GM controversy. Wealth is decomposed into total land value and net returns, where land value is denoted by $P_l\bar{A}$, with P_l defined as the per acre price of land, and $\bar{A}$ is the total acreage in the crop. Wealth is defined as

$$W = P_l\bar{A} + (PY_c - C_c - Z_c)A_c + \big((P - d)Y_{gm} - C_{gm} - Z_{gm}\big)A_{gm}.$$

The producer allocates acreage between the GM crop and the conventional crop in order to maximize the expected utility of end-of-period wealth ($EU[W]$, $U'[W] > 0$, $U''[W] < 0$):

$$\text{(1)} \qquad \max_{A_c, A_{gm}} EU\Big[P_l\bar{A} + (PY_c - C_c - Z_c)A_c + \big((P - d)Y_{gm} - C_{gm} - Z_{gm}\big)A_{gm}\Big]$$

$$\text{s.t.: } A_c + A_{gm} \leq \bar{A},\ A_c \geq 0,\ A_{gm} \geq 0.$$

For purposes of illustration, we assume that the crop yields and pest control costs of the conventional crop and GM crop are independent: $\text{cov}(Y_{gm}, Y_c) = 0$, $\text{cov}(Z_{gm}, Z_c) = 0$, $\text{cov}(Y_{gm}, Z_{gm}) = 0$, and $\text{cov}(Y_c, Z_c) = 0$. The price discount on GM crops is assumed to be independent of the individual producer's GM crop yield, or $\text{cov}(d, Y_{gm}) = 0$.

To solve for the interior solution, we assume complete land utilization, $A_c + A_{gm} = \bar{A}$. The first-order condition is specified as:

$$\frac{\partial U(W)}{\partial A_{gm}} = E\left[U'(W)\frac{\partial W}{\partial A_{gm}}\right] = 0.$$

In order to solve this first-order condition, we take a first-order Taylor series expansion of $U'(W) = U'(\bar{W}) + U''(\bar{W})[W - \bar{W}]$ evaluated at expected end-of-period wealth, $\bar{W}$. After substituting for $U'(W)$ and $\bar{W}$, dividing by $U'(\bar{W})$, and taking expectations, we obtain the following:

$$\frac{1}{U'(\bar{W})}\frac{\partial U(W)}{\partial A_{gm}} = ER_{gm} - ER_c - \bar{\phi}\left[A_{gm}(\text{var}(c) + \text{var}(gm)) - \bar{A}\,\text{var}(c)\right] = 0,$$

where

$$ER_{gm} = \left((P - \bar{d})\bar{Y}_{gm} - C_{gm} - \bar{Z}_{gm}\right),$$

$$ER_c = (P\bar{Y}_c - C_c - \bar{Z}_c),$$

$$\text{var}(c) = (P^2\sigma^2_{Y_c} + \sigma^2_{Z_c}),$$

$$\text{var}(gm) = \left((P^2 + \bar{d}^2 + \sigma^2_d)\sigma^2_{Y_{gm}} + \bar{Y}^2_{gm}\sigma^2_d + \sigma^2_{Z_{gm}}\right), \text{ and}$$

$$\bar{\phi} = -\frac{U''(\bar{W})}{U'(\bar{W})}.$$

As defined, $\bar{\phi}$ is the coefficient of absolute risk aversion evaluated at expected end-of-period wealth, $\bar{W}$.

INTERIOR SOLUTION. *If the producer plants both crops, then acreage is allocated according to the following rules:*

$$A_c = \frac{ER_c - ER_{gm} + \phi\bar{A}\,\text{var}(gm)}{\phi(\text{var}(c) + \text{var}(gm))} \tag{2}$$

and

$$A_{gm} = \frac{ER_{gm} - ER_c + \phi\bar{A}\,\text{var}(c)}{\phi(\text{var}(c) + \text{var}(gm))}. \tag{3}$$

When the producer plants both crops, the optimal acreage allocation is based on two components: first, the ratio of the difference in the expected returns of the conventional and GM crop, and the total variance, weighted by the farmer's risk preferences; and second, the percentage of the total variance attributed to the alternative crop. The acreage in the conventional (GM) crop will increase as the expected returns for the conventional (GM) crop increase relative to the expected returns for the GM (conventional) crop and as the variance of the GM (conventional) crop increases relative to the variance of the conventional (GM) crop.

Table 1 reports the comparative static results for the interior solution to the producer's utility maximization problem. The predictions are largely the same as those for the standard two-crop allocation problem, although we emphasize pest control cost variability and relative price variability. The producer will allocate less acreage to a crop if there is an increase in its expected pest control costs, and in the variance of either yield or pest control costs. When the expected yield of the conventional crop increases, the

Table 1. Comparative Statics for the Producer's Acreage Allocation Decision

Variable	GM Crop (A_{gm})	Conventional Crop (A_c)
Price (P)	?	?
Discount (d)	–	+
Variance of discount (σ_d^2)	–	+
Expected yield of GM crop ($\bar{Y}_{gm}$)	?	?
Expected yield of conventional crop ($\bar{Y}_c$)	–	+
Expected pest control costs for GM crop ($\bar{Z}_{gm}$)	–	+
Expected pest control costs for conventional crop ($\bar{Z}_c$)	+	–
Yield variance for GM crop ($\sigma_{Y_{gm}}^2$)	–	+
Yield variance for conventional crop ($\sigma_{Y_c}^2$)	+	–
Variance of pest control costs for GM crop ($\sigma_{Z_{gm}}^2$)	–	+
Variance of pest control costs for conventional crop ($\sigma_{Z_c}^2$)	+	–
Arrow-Pratt coefficient of risk aversion (ϕ)	?	?

Table 2. Producers' Subjective Views on Mean and Variance of GM Crop Yields and Total Costs per Bushel Relative to Conventional Varieties (C), Based on Production and Cost Characteristics

Description	Roundup Ready Soybeans (RR)	Bt Corn (Bt)	Roundup Ready Corn (RR,c)	Liberty Link Corn (LL)
Expected yield	$\bar{Y}_{RR} < \bar{Y}_C$	$\bar{Y}_{Bt} > \bar{Y}_C$	$\bar{Y}_{RR,c} = \bar{Y}_C$	$\bar{Y}_{LL} = \bar{Y}_C$
Production costs	$C_{RR} > C_C$	$C_{Bt} > C_C$	$C_{RR,c} > C_C$	$C_{LL} > C_C$
Pest control costs	$\bar{Z}_{RR} < \bar{Z}_C$	$\bar{Z}_{Bt} = 0$, $\bar{Z}_C > 0$	$\bar{Z}_{RR,c} < \bar{Z}_C$	$\bar{Z}_{LL} < \bar{Z}_C$
Expected total cost/bushel	$ETC_{RR} < ETC_C$	$ETC_{Bt} > ETC_C$	<-- depends on weed pressure -->	
Yield variance	$\text{var}(Y_{RR}) < \text{var}(Y_C)$	$\text{var}(Y_{Bt}) < \text{var}(Y_C)$	$\text{var}(Y_{RR,c}) < \text{var}(Y_C)$	$\text{var}(Y_{LL}) < \text{var}(Y_C)$
Variance of pest control costs	$\text{var}(Z_{RR}) < \text{var}(Z_C)$	$\text{var}(Z_{Bt}) = 0$ $\text{var}(Z_C) > 0$	$\text{var}(Z_{RR,c}) < \text{var}(Z_C)$	$\text{var}(Z_{LL}) < \text{var}(Z_C)$
Variance of total cost/bushel	$\text{var}(TC_{RR}) < \text{var}(TC_C)$	$\text{var}(TC_{Bt}) < \text{var}(TC_C)$	$\text{var}(TC_{RR,c}) < \text{var}(TC_C)$	$\text{var}(TC_{LL}) < \text{var}(TC_C)$

producer will allocate more acreage to the conventional crop. In contrast, due to the price uncertainty associated with the GM crop, the sign is ambiguous for the producer's acreage allocation for both the GM crop and the conventional crop when the expected yield increases for the GM crop. If there is a certain price discount, so that $\sigma_d^2 = 0$, then the producer would increase the acreage allocated to the GM crop when the expected yield of the GM crop increased.

A more risk-averse producer will be more sensitive to changes in the variance of total profit attributable to each crop, and will make larger changes to his acreage allocations than a less risk-averse producer. The producer will increase (decrease) acreage in the GM crop if the variance in profits attributable to the conventional (GM) crop increases relative to the variance in profits attributable to the GM (conventional) crop. If the relative shares of the profit variance of each crop are unchanged by the GM controversy, the producer will not change his acreage allocation.

The theoretical model is paired with focus group findings related to producer concerns about price risk, and producers' evaluation of the production risks and returns associated with planting GM crops relative to conventional crops (summarized in table 2). Following the focus group finding that producers perceived an increase in the price risk for GM crops between the 1999 and 2000 crop years due to the GM controversy, we offer two testable hypotheses for producers at an interior solution in 1999. Acceptance of these hypotheses would imply that the uncertain price effects of the GM controversy dominated any offsetting production considerations. First, an increase in the expected price penalty or the variance of the price penalty results in an acreage increase for the conventional crop and an acreage decrease for the GM crop.

- **TESTABLE HYPOTHESIS 1 (TH1).** *For producers who planted both GM and conventional seed in 1999, the share of acres in GM seed will decrease in 2000, ceteris paribus.*

The alternative hypothesis for the theoretical model is that production considerations outweighed price risk. If, as indicated by the focus groups, GM soybeans offer substantial production benefits, we would expect TH1 to be rejected for GM soybeans. Its acceptance or rejection for GM corn will depend on the relative importance of GM corn's lower cost variance, higher average cost per bushel, the expected price discount, and the variance of the price discount. More broadly, an alternative hypothesis outside the model is that factors other than risk and risk attitudes determine planting decisions. For instance, constraints on labor or on managerial effort may be driving acreage allocation decisions.

For an interior solution, both the direction and the magnitude of the changes in producers' acreage allocations depend on their degree of risk aversion. Assuming the degree of the producers' risk aversion is independent of the crops, we offer testable hypothesis 2.

- **TESTABLE HYPOTHESIS 2 (TH2).** *A producer's changes in acreage allocations for GM corn and GM soybeans in 2000 will be positively correlated.*

CORNER SOLUTIONS. *The conditions for the producer to plant a single crop are:*

A. *The producer will plant all acreage in the GM crop if* $ER_{gm} \geq ER_c + \phi \bar{A}\,\mathrm{var}(gm)$.

B. *The producer will plant all acreage in the conventional crop if* $ER_c \geq ER_{gm} + \phi \bar{A}\,\mathrm{var}(c)$.

C. *If the expected return from the conventional (GM) crop is higher than the expected return from the GM (conventional) crop, and the variance of the conventional (GM) crop is lower than the variance of the GM (conventional) crop, then the producer will plant all acreage in the conventional (GM) crop.*

Condition A(B) is met when the expected returns from the GM (conventional) crop meet or exceed the expected returns from the conventional (GM) crop and the disutility from the risk associated with the GM (conventional) crop. Condition C is met when the expected returns from the GM (conventional) crop stochastically dominate the conventional (GM) crop, and identifies when the production characteristics of the GM crop will dominate the price risk due to the GM controversy. Returning to producers' characterizations of alternative crops summarized in table 2, note these conditions are more likely to be met for Roundup Ready soybeans than for conventional soybeans. For corn, conditions A and B are more likely to be met for conventional corn than for Bt corn, and condition C is unlikely to be relevant.

While it is more difficult to derive robust testable hypotheses for those producers who were at a corner solution in 1999, we offer the following, admittedly weak, tests. If a producer allocated all acreage to the conventional crop in 1999, indicating the GM crop was not profitable, then the producer will continue to find the GM crop unprofitable in 2000, due to the introduction of increased price risk for the GM crop.

- **TESTABLE HYPOTHESIS 3 (TH3).** *Producers who planted only conventional seed in 1999 will continue to do so in 2000.*

Acceptance of this hypothesis is consistent with a producer maximizing expected utility, or maximizing expected profits. In contrast, if this hypothesis is rejected, it provides support for the hypothesis that there is no effect of price uncertainty due to the GM controversy on producers' acreage allocation decisions.

Hypotheses 1–3 predict that producers who are more risk averse are less likely to plant GM crops. However, many producers planted 100% GM soybeans in 1999. For producers at this corner solution, the introduction of a possible price penalty may or may not affect their acreage allocation of GM soybeans. Their response will depend on the size of the possible price penalty, their degree of risk aversion, and the magnitude of the production advantages of GM soybeans relative to conventional soybeans. Nonetheless, if the GM controversy has an important effect on planting decisions, no additional producers will move to this corner solution.

- **TESTABLE HYPOTHESIS 4 (TH4).** *No producers will plant 100% GM soybeans in 2000 who did not do so in 1999.*

One alternative hypothesis is the possibility that respondents are risk neutral. In contrast to a risk-averse producer, a risk-neutral producer will always plant all acreage in the variety with the higher expected return in our framework. In order to differentiate between risk-averse and risk-neutral producers as the dominant group in the sample, we examine whether or not producer risk attitudes, as measured by survey responses, are a significant explanatory factor for acreage allocation decisions.

Econometric Model

The producers' solution to the acreage allocation problem depends on expected returns from each crop, the expected price discount for GM crops, the variance of returns from each crop, the land constraint, their wealth level, and their risk preferences. The 2000 GM share variables are truncated; there are many producers with either 0% or 100% GM corn or soybeans in 2000. Hence, corn and soybean acreage allocation is modeled using a two-limit Tobit model, where y_t^* is a latent variable representing the farmer's beliefs about the profitability of the crop, $\mathbf{x}_t$ 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^2, and $t = 1, ..., n$, where n is the number of observations:

$$y_t^* = \beta' \mathbf{x}_t + \varepsilon_t . \tag{4}$$

However, the farmer's observed behavior is the share of corn and soybean acreage in GM and conventional crops, y_t, which is bounded by 0 and 1:

$$y_t = \begin{cases} 0 & \text{if } \; y_t^* \le 0, \\ y_t & \text{if } \; 0 \ge y_t^* \ge z, \\ 1 & \text{if } \; y_t^* \ge z. \end{cases} \tag{5}$$

If the farmer believes the GM crop is not profitable, then he will not adopt it. Alternatively, if the farmer believes GM corn is more profitable than the alternative crop, where the alternative yields profits of z, then the GM crop will be adopted.

Based on the theoretical model, the independent variables that explain adoption include the expected returns associated with conventional and GM crops, the variances and covariances between the conventional and GM crops, the total number of acres operated, the farmer's risk preferences, and the farmer's wealth. The farmer's wealth level (W) is proxied by the value of the planted acres owned by the producer.[3] Farmers with more wealth will be less likely to shift away from GM crops. The expected returns for each crop will depend on the producer's ability, which increases with schooling and experience (Welch; Huffman; Feder, Just, and Zilberman). Years of schooling is included as a proxy for ability.[4] Total acres ($\bar{A}$) are defined as total operated acres planted to either soybeans or corn in 2000 (Marra and Carlson). We include the farmer's 1999 gross farm income as a second measure of farm size, since it captures the size of the farm's livestock and row crop operations. Larger operations will be less responsive to the GM controversy for two reasons: First, larger farms tend to be more diversified; and second, larger farms require more management, and GM crops tend to require less management effort.

In order to examine alternative hypotheses, we also include the number of crop operations, and the number of livestock operations which are expected to capture both wealth effects in terms of equipment and buildings, and management effort. Since farms with more operations will require more management effort, these variables are likely to be positively related to the share of GM crops. To capture any labor constraints that may influence the farmer's decision to plant GM crops, the total number of employees on the farm is included. We also incorporate the farmer's 1999 GM crop planting decisions to provide a baseline comparison for the farmer's 2000 decisions, and to reflect the farmer's personal experience with GM crops. The 1999 share of GM crops will reflect whether the farmer's previous experience was positive or negative. For corn, we include the total number of years the farmer has planted GM corn to better capture learning effects and habits.

To capture producer risk preferences ($\phi(W)$), we include an attitudinal index of the farmer's willingness to take risks. Farmers who are more willing to accept risk will be more likely to continue to plant GM crops. The farmer's belief regarding consumer acceptance of biotech food products is used to represent producer beliefs about the

[3] The value of the planted acres is calculated using the 2000 average value of land in the producer's county multiplied by the number of planted acres owned by the farmer. The average value of land in Iowa counties was published in *The Des Moines Register* (Perkins).

[4] Farmer age and years of experience are excluded because they are highly collinear with the years of schooling.

discount for GM crops ($E[d]$, var(d)). Farmers who believe that consumers will reject some biotech food products will be less likely to plant GM crops. For corn, we also incorporate an attitudinal variable eliciting the producer's concern about yield damage from the European corn borer, which is expected to positively influence the planting of Bt corn.

Survey Data

Survey data were collected with the cooperation of the Iowa Farm Bureau Federation. Mail surveys were sent to a sample of 1,000 Iowa Farm Bureau members who grow corn and plant at least 100 acres of row crops. Survey recipients were randomly selected from within the group meeting these two conditions. The first wave of the survey was mailed February 9, 2000, and a second copy was sent to nonrespondents on March 1, 2000. The gross response rate was 43%. After excluding the undeliverable surveys, 389 usable responses were obtained.[5]

The data set contains information on acreage allocations for both corn and soybeans. For corn, producers reported the acres they planted in different specialized traits for 1997–1999, and how many acres they intended to plant in 2000. Specialized traits included in the survey were Bt corn, Roundup Ready corn, Liberty Link corn, Clearfield (IMI) corn, high oil corn, white corn, stacked traits, and all other specialized corn. For soybeans, producers reported the acres they planted in different specialized traits in 1999, and how much they intended to plant in 2000. Specialized traits for soybeans included in the survey were Roundup Ready, STS, and other specialized traits. Producers also answered questions regarding their attitudes toward risk and biotechnology, farm operations, and personal demographic characteristics.

To capture producer attitudes about the consumer response to products from biotechnology and risk, we have adopted attitudinal questions developed by Barham. To elicit the respondent's perception of consumer acceptance of biotechnology food products, respondents were asked to strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, or strongly disagree with the following statement: "Consumers will not accept some food products from biotechnology." In order to reduce noise, each of the respondents' scores was converted to a z-score, with property of mean 0 and a standard deviation of 1.

To elicit their attitudes about risk, respondents were asked to strongly agree or disagree (using the same scale as above) with the following statements: (a) "I would rather take more of a chance on making a big profit than be content with a smaller but less risky profit"; (b) "I regard myself as the kind of person who is willing to take more risks than the average farmer"; and (c) "Farmers who are willing to take chances usually do better financially." From this set of questions, we generated an index of an individual's willingness to accept risk. To develop the index, each of the respondents' scores was converted to a z-score. Questions with a negative correlation were reverse-scored, so that high scores for each question were consistent. This index had a Cronbach's alpha reliability coefficient of 0.73.[6]

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[5] Undeliverable surveys were those for which the addressee was retired, a landlord, or deceased.

[6] Cronbach's alpha is a coefficient of reliability, and it depends on the number of variables and the average covariances between all the variables. It identifies how well a set of variables measures a single unidimensional latent construct. Cronbach's alpha reliability coefficients above 0.60 are considered satisfactory.

Of course, this study's sample may not necessarily represent all Iowa producers. Our cooperation with the Iowa Farm Bureau may have resulted in an attitudinal bias, relative to all Iowa producers. Given the American Farm Bureau Federation's (AFBF's) advocacy of consumer education for GM crops, the farmers in our sample are expected to be more accepting of GM crops relative to farmers who do not belong to the Farm Bureau.[7] Less subjectively, the sample is deliberately biased toward producers with larger farms relative to the overall population of producers. Small producers were eliminated (less than 100 acres of row crops) from our sample in order to obtain a better idea of the factors driving total acreage allocation decisions from a sample of a given number of producers. Farms of 100 acres or more accounted for only 58.6% of Iowa farms, but accounted for 90.2% of Iowa corn production in 1997 [U.S. Department of Agriculture (USDA)].

Most of the differences between our sample and the population of Iowa farmers, as measured by the USDA's National Agricultural Statistics Service, can be explained by our minimum size requirement. For instance, the survey respondents had larger gross farm incomes than Iowa farmers as a whole. According to Sands and Holden, 26% of Iowa farmers had a gross farm income of $10,000 or less in 1999, compared with 2.2% of our sample. For 1999, 62% of respondents had a gross farm income of $100,000 or more compared to 35% of Iowa farmers in 1997. In 1998, the average size of an Iowa farm was 340 acres (Sands and Holden), while, among the survey respondents, the average farm size was 562 acres for the 2000 crop year. A larger share of respondents (84%) are full-time farmers compared to the overall population (62%), which is consistent with full-time farmers operating larger farms than part-time farmers. Overall, we believe that the farmers in our sample—which consists of larger farms and a higher proportion of full-time farmers than the average Iowa farm—are more aware of GM crops, and are therefore more likely to adopt GM crops than the average Iowa farmer.

Results

In the empirical analysis, we first examine farmers' planting intentions for 2000. Second, we test the hypotheses generated by the theoretical model regarding the impact of price uncertainty due to the GM controversy on producer planting decisions.

Planting Intentions of Survey Respondents

Overall, producers in the sample did not substantially change their planned total corn acreage, but they did plan to plant fewer acres to soybeans. Producers reported they expected to plant about 20% fewer acres of soybeans overall (a decline from 116,007 acres in 1999 to 92,463 acres in 2000). Respondents expected to plant only 0.5% fewer acres of corn (a decline from 97,048 acres in 1999 to 97,564 in 2000).

Respondents indicated they intended to plant 13% fewer acres of GM soybeans in 2000 (a decline from 70,252 in 1999 to 61,122 acres). Despite increased demand uncertainty for genetically altered crops, Iowa corn-soybean producers planned to increase

[7] During the controversy, Carl Loop, the vice president of American Farm Bureau Federation, asserted that education is the key to consumer acceptance, and stated: "Otherwise, no one—consumers or farmers—will gain the potential benefits offered by biotechnology" (online at http://www.fb.com/news/nr/nr99/nr1118.html).

Table 3. Percentage of Acres Planted in Genetically Modified Crops: 1999 and 2000

	Acreage %	
Description	1999	2000
Acreage in Roundup Ready Soybeans:		
% of total sample	60.55	66.10
Mean for individual farmers	61.44	63.58
Acreage in Bt Corn:		
% of total sample	30.67	28.60
Mean for individual farmers	25.44	23.65
Acreage in Liberty Link Corn:		
% of total sample	3.428	3.433
Mean for individual farmers	3.238	3.581
Acreage in Roundup Ready Corn:		
% of total sample	1.501	1.396
Mean for individual farmers	1.964	1.996

their acreage share allocated to GM soybeans (table 3). Of the 389 respondents, 61.6% intended to make no change to their acreage allocation. More planned to increase their acreage share in GM soybeans (17.8% of respondents) than to decrease (20.6%). The mean of each individual farmer's 2000 share of soybean acres in Roundup Ready soybeans is significantly higher than the farmer's 1999 level, at the 90% level. This provides statistical support for the focus group finding that production characteristics dominated any effect of price uncertainty for GM soybeans.

In aggregate, respondents intended to plant 6.2% fewer acres to Bt corn in 2000 (a decline from 29,764 acres in 1999 to 27,905 acres in 2000). Fewer farmers planned to plant Bt corn in 2000 than 1999. In 1999, 60.6% of the farmers planted Bt corn. For 2000, 49.9% of the farmers intended to plant Bt corn. The mean of each individual farmer's share of corn acres in Bt corn is lower in 2000 relative to 1999. The decline is significant at the 90% level.

Overall, based on planting intentions for 2000, the acreage planted to herbicide tolerant corn, including Liberty Link and Roundup Ready, was unchanged between 1999 and 2000. Relatively few farmers in the sample planted or intended to plant herbicide tolerant corn; 18% planted herbicide tolerant corn in 1999, and 13% intended to plant herbicide tolerant corn in 2000. There was no significant difference in the mean of each individual farmer's share of corn acres in either Liberty Link or Roundup Ready corn between 1999 and 2000.

Regression Analysis

To test TH1, we use a two-limit Tobit model to regress the 2000 share of GM soybeans on the 1999 share, and the 2000 share of GM corn on the 1999 share, with no constant. Because TH1 only applies to producers at an interior solution in 1999, the sample is restricted to those producers. For TH1, our null hypothesis is that producers initially at an interior solution did not reduce their GM acreage: H_0: $\beta_{GM99} \geq 1$, H_A: $\beta_{GM99} < 1$. Our findings are consistent with the summary statistics presented above. Producers certainly do not plan to reduce their GM soybean acreage, i.e., $\beta_{GM99} = 1.251 > 1$ at the 99%

level (the 95% confidence interval is [1.066, 1.436]). These findings suggest the GM controversy was not the dominant factor in producers' soybean acreage allocation. In contrast, producers are changing their corn acreage allocation in a manner consistent with a response to the GM controversy. As predicted by TH1, producers at an interior solution in 1999 plan to reduce their GM corn acreage in 2000 ($\beta_{GM99} = 0.853 < 1$ at the 99% level; the 95% confidence interval is [0.760, 0.945]).

Table 4 reports regression results regarding the determinants of 2000 planting intentions. For each crop, the dependent variable is the share of acreage planted in GM varieties. The primary factor influencing 2000 planting intentions for GM crops is past experience with GM crops, which reflects a farmer's habits, the amount of information the farmer has about the performance of this new technology, and personal characteristics such as innovativeness. For both GM corn and GM soybeans, the 1999 acreage share explains a large portion of 2000 planting intentions. Further, the strong predictive power of the 1999 acreage share suggests farmers may be near the diffusion ceiling, as hypothesized by Fernandez-Cornejo, Daberkow, and McBride. For GM corn, the number of years the farmer had planted GM corn was positively and significantly related to 2000 planting intentions for the full sample only.

For GM corn, the 2000 share is also explained by attitudes and farm size. Farmers who are concerned about yield damage from ECB are significantly more likely to plant more GM corn (at the 99% level). Consistent with the focus group finding indicating the planting of GM corn is influenced by the controversy surrounding GM crops, agreement with the statement that some consumers will not accept biotech food products had a negative effect on the 2000 share.[8] However, in contrast to our prediction that farmers' risk preferences would influence their reaction to the controversy, their willingness to accept risk does not explain the 2000 share of GM corn. This finding suggests either that farmers are risk neutral, or that the presence of production and other risks obscures the relationship between risk attitudes and the GM controversy, or that the group of questions about the farmer's willingness to accept risk is a poor measure of the farmer's risk preferences. Wealth does not significantly influence the 2000 share of GM corn, but farm size and composition does. Farms with a larger gross farm income, a larger number of crop operations, and a smaller number of livestock operations were significantly more likely to plant a larger share of GM corn. Based on the implications of these findings, farms with a large number of crop activities, where corn and soybeans constitute a relatively small share of the income, are more likely to plant GM crops which require less management effort.

For GM soybeans, the 2000 share is primarily explained by previous experience with GM soybeans. The 1999 gross farm income is positively related to the adoption of GM soybeans. For the full sample, farmers with more years of schooling were significantly more likely to plant a smaller share of GM soybeans in 2000. Consistent with Fernandez-Cornejo and McBride (pp. 16–18), we find that the adoption of GM soybeans is invariant to farm acreage. Fernandez-Cornejo, Daberkow, and McBride attribute this finding to the

[8] Further support for the influence of the controversy on the GM corn planting decision is found when we compare the regression of the 2000 share of GM corn on the explanatory variables excluding the 1999 share, and the regression of the 1999 share of GM corn on the explanatory variables. Notably, the farmer's belief about consumer acceptance of biotech foods has a negative and significant effect on the 2000 share and no effect on the 1999 share. The index related to the farmer's willingness to accept risk has no effect on the 2000 share or the 1999 share of GM corn. The same set of regressions was also performed for GM soybeans, with findings showing both the 1999 and 2000 shares were invariant to the farmer's willingness to accept risk and the farmer's belief about consumer acceptance.

Table 4. Tobit Regressions on 2000 GM Acreage Share: Farmers at the Interior in 1999, and Full Sample

	Subsample: Interior in 1999		Full Sample	
Description	2000 Share GM Corn	2000 Share GM Soybeans	2000 Share GM Corn	2000 Share GM Soybeans
Share of GM corn 1999	0.934***		1.203***	
	(9.82)		(13.51)	
Share of GM soybeans 1999		1.402***		2.247***
		(6.92)		(10.43)
Total corn acreage 2000 (100s)	-0.013		-0.023**	
	(1.44)		(2.38)	
Total soybean acreage 2000 (100s)		0.002		0.018
		(0.12)		(0.61)
Years planting GM corn	0.018		0.054**	
	(0.61)		(1.97)	
Farmer agrees is willing to take risks	0.049	-0.051	0.039	-0.090
	(1.63)	(0.83)	(1.34)	(1.14)
Consumers will not accept biotech food products	-0.044**	-0.055	-0.042*	-0.060
	(2.08)	(1.25)	(1.92)	(0.98)
Concern about yield damage from ECB	0.107***		0.068***	
	(4.32)		(2.74)	
1999 gross farm income ($100,000s)	0.045**	0.066*	0.055***	0.082
	(2.34)	(1.68)	(2.80)	(1.56)
Value of farmland ($100,000s)	-0.002	0.0004	0.002	-0.003
	(0.50)	(0.07)	(0.52)	(0.42)
Number of livestock operations	-0.057**	0.024	-0.054**	0.027
	(2.37)	(0.47)	(2.25)	(0.41)
Number of crop operations	0.063**	-0.045	0.050*	0.052
	(2.22)	(0.78)	(1.75)	(0.66)
Years of school	0.022	-0.011	-0.002	-0.101***
	(0.17)	(0.48)	(0.18)	(3.26)
Number of employees	-0.011	-0.072	0.061	-0.099
	(0.16)	(0.49)	(0.90)	(0.56)
Constant	3.013	21.833	-19.072	30.727
	(0.14)	(0.49)	(0.92)	(0.57)
Number of observations	200	110	315	324
Pseudo R^2	0.50	0.25	0.56	0.34

Notes: Single, double, and triple asterisks (*) denote significance at 90%, 95%, and 99%, respectively. Numbers in parentheses are absolute values of *t*-statistics.

degree of adoption of GM soybeans; the adoption of GM soybeans is beyond the innovator and early adopter stages which are the most sensitive to farm size. As expected, risk preferences, as measured by the risk index, do not explain the share of GM soybeans. In addition, the farmer's wealth level does not explain the 2000 share of GM soybeans.

As predicted in TH2, there will be a positive relationship between the change in share of corn and soybeans in GM acreage for 1999 and 2000, provided farmers' risk preferences are independent of the crop. For a risk-neutral producer, an inability to reject TH2 would suggest the expected GM price discount is positively correlated across crops. However, rejecting TH2 in favor of a negative relationship in the acreage response for corn and soybeans would be consistent with our findings that producers had a different acreage response to the controversy for GM corn and GM soybeans, due to their different production characteristics.

For the full sample, the relationship between the percentage change in GM corn and percentage change in GM soybeans is positive, but insignificant ($\beta = 0.066$). For farmers at an interior solution in 1999 for both GM corn and GM soybeans, a positive and weakly significant relationship is observed at the 90% level in the acreage responses ($\beta = 0.192$). There is no relationship between the change in share of GM corn and GM soybeans between 1999 and 2000. Overall, this result implies either our assumption that farmers' risk preferences are independent of the crop is incorrect, or farmers have heterogeneous expectations regarding GM price discounts for corn and soybeans.

As stated in TH3, producers who planted only conventional seed in 1999 are predicted to continue to plant only conventional seed in 2000. While most producers who were conventional only in 1999 behaved as predicted, a number of producers decided to plant GM soybeans or GM corn in 2000. Therefore, we reject TH3 for both corn and soybeans. For soybeans, of the 71 producers who planted 100% conventional in 1999, 16 chose to plant at least some GM soybeans in 2000. Of the 108 producers who planted 100% conventional corn in 1999, 13 elected to plant at least some GM corn in 2000.

TH4 predicts, given the price risk associated with GM crops in 2000, no more producers will plant 100% GM in 2000 than in 1999. We reject TH4 for both corn and soybeans. Of the 187 soybean producers who planted less than 100% GM in 1999, 38 decided to plant 100% GM soybeans in 2000. For corn, of the 304 producers who planted less than 100% GM in 1999, six chose to plant 100% GM corn in 2000. These rejections reveal that price risk due to the GM controversy is not the primary consideration influencing producer acreage allocation decisions.

Conclusion

This study examines the importance of the GM controversy for Iowa corn-soybean farmer acreage allocation decisions, using a model of a risk-averse producer's utility of profits. One possible outcome of the controversy is that producers will face a price penalty on GM crops. Hence, decisions are examined in the presence and absence of price risk to represent producers' spring 2000, and spring 1999 planting decisions, respectively. We test our model using data collected from a survey of Iowa Farm Bureau members who plant at least 100 acres of row crops. While the survey sample does not include small farmers, it is reasonably representative of the producers responsible for the majority of corn production in Iowa. In the absence of the focus group data on producers' beliefs about GM crops, risk-averse producers would be predicted to reduce their acreage in all GM crops as a result of the increased demand uncertainty in spring 2000 relative to spring 1999. However, given producers' comments regarding the significant production benefits of GM soybeans, we instead predicted that producers may increase their acreage in GM soybeans. Survey results confirm that producers plan to decrease their acreage in GM corn and increase their acreage in GM soybeans. These findings emphasize the importance of considering all characteristics of alternative crops when examining the potential effects of a demand shock.

Our analysis of the factors affecting producers' 2000 acreage allocation decisions was inconclusive with respect to the role of farmers' risk preferences. These risk preferences, as measured by an index of farmers' responses to questions about their willingness to accept risk, did not explain their 2000 planting decisions. This finding may suggest that farmers are risk neutral, assuming the index accurately captures their risk preferences. Alternatively, this finding may be due to the inaccurate measurement of risk preferences by the index. This ambiguity demonstrates a need for further research on measuring risk preferences, and on the influence of risk preferences on farmers' acreage allocation decisions.

One factor which will undoubtedly affect acreage allocations in the future is premiums for non-GM varieties. While premiums are increasing for some local markets, such as non-GM soybeans in Indiana, the future and size of these premiums is uncertain. The European Union is considering revising its GM tolerance levels. Many developing countries have not determined their GM foodstuffs policies. The market for non-GM crops is still evolving, and will be partially determined by such policy decisions.

Consumers' attitudes toward GM foods will also determine the market for non-GM crops. First, price premiums at the farmgate require final consumers who will pay more for non-GM foods. Second, perceived consumer reluctance to accept some GM foods reduced survey respondents' acreage allocation decisions in our analysis, even without any known price premiums (or evidence that risk attitudes affected acreage allocation). Any future changes in consumer attitudes may directly affect acreage allocations as well. Farmers' use of consumer attitudes in their production decisions, even in the absence of direct price signals, is likely to become more important as consumers become increasingly concerned about the manner in which their food is produced.

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