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Farmers' Adoption of Genetically Modified Varieties with Input Traits

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UC PEER REVIEWED

This publication has been anonymously peer-reviewed for technical accuracy by University of California scientists and other qualified professionals. -

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EXECUTIVE SUMMARY

The decision to adopt a new technology depends on its expected profitability. The expected profitability of an innovation depends on the suitability of the innovation, given its characteristics, for a specific farmer and farm, given their characteristics. We examine the determinants of the adoption of genetically modified (GM) corn and soybean varieties by Iowa producers using data collected from a survey of producers. Between the 1999 and 2000 crop years, the controversy regarding GM foods intensified. We conducted focus groups, as well as our survey, between the 1999 and 2000 crops, which allowed us to assess the effects of the intensification of the controversy on producers' planting decisions empirically.

Farmers did not necessarily react to the GM controversy in the same way for corn and soybeans; all permutations of increases and decreases for corn and soybeans were observed for individual survey respondents. The representative farmer increased or held constant his GM soybean acreage but decreased his GM corn acreage, consistent with the dynamic diffusion analysis in Fernandez-Cornejo, Alexander, and Goodhue.

This behavior was consistent with the intentions of focus-group participants, who identified production risks and returns for GM soybeans that offset price risk due to the GM controversy for soybeans. In contrast, production risks and returns for GM corn reinforced this price risk. Further reinforcing these findings, descriptive analysis of our survey data suggested that producers who first adopted GM soybeans in 2000 were both more risk-averse than other growers and agreed more strongly that consumers would not accept some bioengineered foods.

We constructed a theoretical model using the risk and return properties of GM and non-GM crops obtained from the focus groups. The model predicted behavior consistent with the above findings. We then tested it using the survey data. Agreement with the statement that consumers will not accept some bioengineered foods was associated with a significant decline in the intended share of acreage devoted to GM corn but had no explanatory power for GM soybean planting intentions. Risk attitudes did not prove to be a significant explanatory factor, perhaps due to the existence of production risk and price risk, which may have offset each other in the acreage-allocation decision.

Other factors that were found to be significant in determining adoption decisions in our econometric analysis of our survey data included gross farm income, the previous year's acreage allocation, agreement with the statement that farmers will benefit from biotechnology, years of schooling (soybeans only), total corn acreage (corn only), and concern regarding European corn-borer yield damage (corn only). An increase in gross farm income was associated with an increase in the share of GM acreage for both crops as commonly predicted by the adoption literature. The previous year's GM acreage share for that crop was highly significant, consistent with models of the adoption process and our findings from the dynamic diffusion analysis.

For the full corn sample, which included farmers with all or none of their acreage in GM varieties, an increase in total corn acreage was associated with a decrease in the share of corn acreage allocated to GM hybrids. For the full soybean sample, farmers with fewer years of schooling allocated a higher share of acreage to GM soybeans. This is consistent with the observation made by focus-group participants that planting herbicide-resistant soybeans varieties reduced management requirements.

INTRODUCTION

Increasingly, advances in plant breeding are widening the range of crop varieties. Corn and soybean producers can now purchase seed that reduces other variable production costs or yields a product with a specific quality characteristic. Such seeds are transforming agricultural input and output sectors; the seeds provide alternatives to pesticides, expand the range of available herbicide-application method-timing choices, and create products with output-enhancing traits, such as high oil content.

Some of these seeds are genetically modified (GM) using recombinant DNA techniques. By a precise alteration of a plant's traits, genetic modification facilitates the development of characteristics not possible through traditional plant breeding techniques. By targeting a single plant trait, it can decrease the number of unintended characteristics that may occur with traditional breeding. We consider GM corn and soybean varieties with herbicide-tolerant and insect resistant traits.

GM crops carrying herbicide-tolerant genes were developed to survive certain broad-spectrum herbicides. Previously, these herbicides would have destroyed the crop along with the targeted weeds. Thus, herbicide-tolerant crops have provided farmers a broader variety of postemergent herbicides. The most common herbicide-tolerant crops are Roundup Ready® (RR) crops resistant to glyphosate—an herbicide effective on many species of grasses, broadleaf weeds, and sedges. Glyphosate tolerance has been incorporated into soybeans, corn, canola, and cotton. Other GM herbicide-tolerant crops include Liberty Link® (LL) corn, which is resistant to glufosinate-ammonium, and BXN cotton, which is resistant to bromoxynil. There are also traditionally bred herbicide-tolerant crops, such as corn resistant to imidazolinone (IMI) and sethoxydim (SR), and soybeans resistant to sulfonylurea (STS®). Adoption of herbicide-tolerant soybeans has been particularly rapid compared to adoption of other agricultural innovations. Herbicide-tolerant soybeans became available to farmers for the first time in limited quantities in 1996, and usage expanded from about 7 percent of the soybean acreage in 1996 to more than 50 percent nationwide in 2000.

Corn and cotton genetically engineered to contain a gene from the soil bacterium *Bacillus thuringiensis* (Bt) were the only insect-resistant GM crops commercially available during the study period. These crops are referred to as Bt crops. The introduced gene which produces a protein that is toxic when ingested by certain Lepidopteran insects, such as the European corn borer. The Environmental Protection Agency (EPA) approved Bt corn in August 1995. Its use grew from about 1 percent of planted corn acreage in 1996 to about 26 percent in 1999 before falling to 19 percent in 2000.

The development of varieties with new traits through traditional plant breeding and genetic modification is occurring concurrently with a movement of agricultural research from the public to the private sector. Many important innovations are the patented intellectual property of private firms. There has been much discussion of the implications of this shift for the distribution of benefits of agricultural research as well as the direction and amount of future agricultural research (Just and Hueth; Moschini and Lapan; Alston, Sexton, and Zhang; Moschini, Lapan, and Sobolevsky; Hennessy; Flack, Traxler, and Nelson; Goodhue et al.; Rausser; Alexander and Goodhue). The research reported here focuses on the factors underlying farmers' adoption decisions as one of the factors influencing the direction of private firms' agricultural research. As a profit maximizer marketing a new product, a private firm is concerned with the costs of producing the product, and the revenues. Revenues are determined by the demand for the seed, which is a function of planted acreage and the seeding rate per acre. Clearly, farmers' adoption decisions influence the profitability of innovation.

The decision to adopt a new technology depends on its expected profitability. The expected profitability of an innovation depends on the suitability of the innovation, given its characteristics, and the characteristics of the farmer and the farm. Previous studies suggest that farmers with more human capital (e.g. schooling and experience) are more likely to profit from an innovation, since human capital is a determinant of allocative ability (Kislev and Shchori-Bachrach; Huffman; Feder, Just, and Zilberman; Welch). However, it is also possible that human capital may substitute for a particular innovation. Farmers who are more concerned about yield damage from weeds and insects will be more likely to adopt preventive innovations. Previous studies suggest that farmers with larger farms are more likely to adopt because fixed costs of adoption are relatively smaller for larger farms and returns from adoption are sometimes directly related to farm size (Lindner; Feder, Just and Zilberman; Feder and Slade; Marra and Carlson). However, specific innovations may have size biases that favor smaller farms.

Farmer beliefs and the institutional setting play a role (Kinnucan et al.). Adoption is dependent on farmers' risk preferences. When the profitability of an innovation is uncertain, farmers who are more risk-averse will be less likely to adopt it (Feder, Just, and Zilberman; Chavas and Holt 1990; Pope and Just). Fernandez-Cornejo and McBride examine producers' adoption of bioengineered varieties for the United States as a whole. Beliefs, institutions, and risk are particularly important considerations for the adoption of specialized traits. Output-enhancing traits require specialized marketing institutions and face additional production and price risks. Between the 1999 and 2000 crop years, when our survey was conducted, the intensification of the GM controversy increased the possibility of price and other marketing risks for GM varieties. However, GM cost-reducing traits also mitigated some production risks.

In order to obtain some insight into these relationships, we focus on two particular aspects: (1) value added versus production cost-reducing traits, and (2) the impact of the GM controversy between spring, 1999, and spring, 2000. We address the following questions:

- What factors influence the adoption of production cost-reducing and output-enhancing traits by producers?
- What effect, if any, did the GM controversy have on producers' adoption decisions for the 2000 crop year?

We conducted focus groups with Iowa corn-soybean producers in the winter of 1999–2000 that addressed these questions. The focus groups were also used to pretest a survey of Iowa corn producers (who were Farm Bureau members) that was conducted in the spring of 2000. We present the focus-group methodology and findings in the next section, followed by the survey design and descriptive statistics summarizing the survey findings. We then introduce a theoretical model of an individual producer's adoption decision. The model is tested using data from the survey, and then we conclude with a summary of our findings.

We found that farmers who believed that the GM controversy would lead consumers to reject some GM foodstuffs had significantly lower shares of corn acreage planted with GM varieties but did not have significantly different soybean shares. Consistent with the predictions of the adoption literature, higher gross farm income increased the use of GM varieties. The previous year's allocation decision was a strong predictor of farmers' allocation choices. Perhaps the most striking finding of our study, however, was the relatively limited adoption of output-enhancing corn traits. This was due to a number of specific factors. In brief, these traits were not economically viable for most producers, particularly the high-oil trait. Our findings suggest that expectations regarding the adoption of these traits by commodity growers may need to be adjusted downward.

FOCUS GROUPS

As part of our research, we utilized focus groups. A focus group is a structured group interview that uses a trained moderator and a preprepared script. In terms of collecting information from a number of individuals in a structured way, focus groups fall between unscripted individual interviews and a formal survey. Interactions among group participants often provide more complete information to the researchers than individual interviews. Focus groups, however, are not an effective means of collecting precise quantitative information for formal statistical analysis as surveys do. Focus groups are useful for developing hypotheses, for pretesting surveys, and for gathering qualitative information, among other purposes. Our focus groups aided us in all three areas. Focus groups aid in gathering information that is difficult to elicit through a survey. Focus groups may help further define a research question before developing a survey form and/or a formal theoretical model.

Three focus groups were conducted with a total of 21 participants in cooperation with the Iowa Farm Bureau Federation: two groups in Mason City in north-central Iowa on December 14 and 15, 1999, and one in Albia in south-central Iowa on January 5, 2000. The focus groups included a discussion on how farmers choose which varieties to plant as well as pretesting of the survey questionnaire. In Appendix A, we include the script used for the focus groups. Four major themes emerged in the focus groups: (1) producers faced low crop prices and other economic difficulties; (2) limited marketing opportunities and other difficulties limited the adoption of varieties with output-enhancing traits; (3) planting decisions for cost-reducing traits varied by region, crop, and producers' previous experience with that trait; and (4) the GM controversy had little or no effect on most producers' planting decisions.

Producers said that they were very concerned about low commodity prices and financial difficulties for the 2000 production year. In particular, in the southern Iowa focus group low prices were significantly altering farmers' production decisions for 2000 relative to 1999. For instance, one farmer planned to keep his variable input costs below $50 per acre.

- *If we grow as good a crop next year as we have the last two years nationwide, it will go from a serious problem to a critical problem and we'll be back into headaches similar to what we experienced in '84 to '86.*
- *I really think it's going to be worse [than '84 to '86] because the inputs are so much higher than they were back then. The only difference that's in our court is that the interest rates are low.*
- *If it wasn't for these government checks, we'd be gone now.*

For value-added traits, farmers in the different areas had different marketing opportunities for specialty crops, such as food grade corn and tofu soybeans. Farmers in our northern Iowa focus groups either never planted specialized corn or did not plan to continue doing so because transportation costs are too high to allow them to compete with central Iowa farmers. Some did plant specialized soybeans, including tofu beans and seed beans. Farmers in our southern Iowa group had more experience with specialty traits. They noted that specialty premiums tended to decline over time and specifically cited high-oil corn and white corn as examples.

- *(High oil) kind of varies from year to year I think on how you contract. Contracts are real spotty. Same way on the white corn.*
- *Everybody talks about added value and the added value erodes after the first season. It's been that way; it's a proven track record. They've trained us to believe that added value will not persist, so why would everybody think added value is great?*

Farmers' adoption of cost-reducing traits varied but was more common than value-added trait adoption. Different areas had different expected yields for corn and soybeans, which affects the benefit of adopting cost-reducing traits. More farmers utilized RR soybeans than cost-reducing trait corn, and their degree of adoption was greater. Previous experience had an important influence on planting decisions, as indicated in the participant comments reproduced below. Participants described the production and cost advantages and disadvantages of the GM crops which are summarized in Table 1.

Table 1. Producer's Subjective Views on the Mean and Variance of GM Crop Yields and Total Costs per Bushel Relative to Conventional Varieties (C) Based on Production and Cost Characteristics

	Roundup Ready® Soybeans (RR)	Bt Corn (Bt)	Roundup Ready® Corn (RR,c)	Liberty Link® Corn (LL)
Expected Yield	$Y_{RR} < Y_c$	$Y_{Bt} > \bar{Y}_c$	$Y_{RR,c} = \bar{Y}_c$	$Y_{LL} = \bar{Y}_c$
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	depends on weed pressure
Yield Variance	$var(Y_{RR}) < var(Y_c)$	$var(Y_{Bt}) < var(Y_c)$	$var(Y_{RR,c}) < var(Y_c)$	$var(Y_{LL}) < var(Y_c)$
Variance of Pest-Control Costs	$var(Z_{RR}) < var(Z_c)$	$var(Z_{Bt}) = 0$ $var(Z_c) > 0$	$var(Z_{RR,c}) < var(Z_c)$	$var(Z_{LL}) < var(Z_c)$
Variance of Total Cost/Bushel	$var(TC_{RR}) < var(TC_C)$	$var(TC_{Bt}) < var(TC_C)$	$var(TC_{RR,c}) < var(TC_C)$	$var(TC_{LL}) < var(TC_C)$

RR soybeans appear to be the most widely used, most successful product. In our southern Iowa focus group, all participants planted 100 percent RR soybeans in 1999. While this was the highest rate of use, producers in northern Iowa also utilized RR soybeans extensively. Most, but not all, participants had some RR soybeans. Very few producers anticipated reducing their use of RR soybeans for 2000. A number of reasons for RR's popularity were centered on its relative cheapness, the simplicity of the weed management program, and the effectiveness of the weed control.

- *I plant 100 percent Roundup® beans. That's got to be the best program out there.*
- *Well, the cost is a big thing, too. It's simple, so simple.*

Herbicide tolerance reduces yield variability but may reduce mean yield in soybeans. However, since a weed management program based on Roundup® is much less expensive than the other alternatives, the RR trait reduces expected total cost per bushel even with lower yields and increased seed costs. Total cost per bushel variability is lower for RR soybeans due to lower yield variability.

Another aspect of planting RR soybeans is that it may be more environmentally friendly than alternative weed control regimes. As one producer noted:

- *Look at if from the safety standpoint of the producer. We're spraying Roundup®, which is not near as lethal as a lot of the other chemicals. And once Roundup® hits the ground, it's done. So, from the safety standpoint, it's a win-win situation for everyone.*

The focus-group participants only used herbicide-tolerant corn in fields with severe weed pressure. The RR and LL traits reduce yield variability but have little effect on average yield. Although weed management programs based on Roundup® and Liberty® herbicides tend to be less expensive, the increased seed cost results in a higher expected total cost per bushel compared to conventional corn unless the corn field has very severe weed pressure. Variability of total cost per bushel is lower due to lower yield variability.

The Bt trait, which confers resistance to the European corn borer, increases mean yield and decreases yield variability. The realization of corn-borer pressure determines whether or not the producer realized a reduction in total cost per bushel from planting the more costly Bt seed. When corn-borer pressure is low, the farmer realizes lower per-bushel costs by planting conventional corn rather than Bt corn (Alexander and Goodhue). Since corn-borer pressure was low in 1998 and 1999, the Bt trait increased realized total cost per bushel in those years. The variability of total cost per bushel is lower for Bt corn than for conventional corn due to lower yield variability.

Producers had a mixed experience with Bt corn. For some, it performed very well and was their best corn. For others, it was consistently their worst performing corn. Farmers in northern Iowa who planted Bt corn tended to utilize it more heavily than the southern

Iowa farmers who planted it did. Lower corn yields in southern Iowa reduce the expected value of Bt corn.

- *I like to plant an early corn and it doesn't stand up well but the Bt of the same variety stands up well.*[1]
- *[19]97 and [19]98, both years there was a lot of stalk rot in the Bt corn. It didn't matter what company or what the number was.*
- *I had some Bt this year, it was my best corn.*

Focus-group participants viewed Bt corn as insurance against corn borers. The Bt trait increases mean yield and decreases yield variability. The variability of total cost per bushel is lower for Bt corn than for conventional corn due to lower yield variability. The realization of corn-borer pressure determines whether or not the producer reduces his total cost per bushel by planting the more costly Bt seed. Corn-borer infestations were low in 1998 and 1999, so many participants incurred a higher realized total cost per bushel from planting Bt corn.

- *We're in a low pressure time and it came right after [Bt] was introduced. For the first two years, everybody wanted it. You can make a case for it, but just barely, and last year was worse.*

In response to their experience in the previous two years, some people intended to reduce the percentage of corn acres planted to Bt corn. In addition, some farmers in southern Iowa plan to reduce their Bt acreage because the most promising new hybrids didn't contain the gene. One producer said:

- *I reduced mine (Bt corn acreage). Basically, the reason I did it, I don't think it's paying its way as far as the corn borer part of it. But there's a lot of new numbers came out this past year too that's non-Bt that I wanted to try.*

Others still viewed it as a reasonably cheap option.

- *Ever since the Bt technology, it's just taken the worry out of it. I think it's very cheap insurance.*

During the focus-group discussions, producers identified three concerns regarding GM crops. All three concerns regard price risk. The three possibilities were a price penalty (either direct or via a segregation requirement), a short-term elevator refusal to take delivery,[2] and a permanent elevator refusal to take delivery.[3]

Focus-group discussions suggested that the GM controversy, especially problems with Europe and other importers, will not have a significant effect on hybrid choices provided that there are no new developments before planting season. A few producers were delaying their seed orders to see if new information emerged, or otherwise adjusting their strategies, but the majority were not. Rather than delay his seed order, one producer chose to insure himself against possible limitation on Bt corn sales:

- *I purchased all non-Bt because I figured if I wanted Bt, I could always get it later. But the non-Bt I thought might be kind of scarce.*

Producers were interested in the marketing implications of any policies enacted regarding GM grains.

- *I'd like to see if they're going to pay a premium for this non-GM.*

Some producers provided a political interpretation of the GM controversy. According to one producer:

- *I think the European nation over there is going to find some fault with anything we try to do. They're just kind of hard nosed against United States agriculture. I'm not saying GMOs are 100 percent safe, because I don't know in my own mind, but I don't think they're as bad as they're leading us to believe either.*

Overall, our focus-group findings did not establish a distinct trend regarding the use of GM seed. For corn, most intended to continue using GM varieties unless a premium emerged for conventionally bred varieties. For soybeans, very few planned to reduce their use of GM varieties. Only a few planned to delay their final seed decision in order to see the effects of the GM controversy. The following sections examine GM use in greater detail.

1 The European corn borer creates holes in the stalk, reducing the standability of the corn. Fallen stalks are often not harvested by the combine, which reduces effective yield. -

2 Farmers with operating loans may incur substantial interest payments if they wait to sell their crop. -

3 Focus-group participants considered this an extreme case that is very unlikely to occur. -

SURVEY

The survey was conducted in cooperation with the Iowa Farm Bureau Federation. One thousand mail surveys were sent to Iowa Farm Bureau members who grew corn and planted at least 100 acres of row crops. Survey recipients were randomly selected within the group meeting these two conditions. The survey was mailed February 9, 2000. A second copy was sent to nonrespondents on March 1, 2000. The gross response rate was 43 percent. There were 389 usable responses after excluding responses for which the addressee was retired, a landlord, or deceased. We eliminated small producers (less than 100 acres of row crops) from our sample 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 produced 90.2 percent of Iowa corn in 1997, but were only 58.6 percent of Iowa farms, according to the 1997 Census of Agriculture. In Appendix C, we compare survey respondents to the representative Iowa producer. Survey topics used in our analysis included questions regarding historical plantings and 2000 planting intentions, farm characteristics, and farmer characteristics, including risk attitudes.

Consistent with our specified selection criterion that the farmer grew corn, 99 percent of the farmers grew corn. The Farm Bureau membership information was based on past activities, so it was not surprising that not every respondent grew corn when surveyed. Consistent with Iowa cropping patterns, the vast majority (94 percent) of respondents grew both corn and soybeans. Roughly half of the respondents grew alfalfa while just under a third grew oats. Less than 5 percent grew other grains or specialty crops.

In the aggregate, producers in the sample did not change their corn acres, but they did plan to plant fewer acres to soybeans. Respondents planned to plant 23,543 fewer acres of soybeans overall (a decline from 116,007 in 1999 to 92,464 acres). According to their planting intentions, producers planned to plant 516 fewer acres of corn (a decline from 97,048 acres in 1999 to 97,564 in 2000). Our respondents' acreage allocations and intentions are compared to U.S. Department of Agriculture (USDA) reports in Appendix B.

Despite increased demand uncertainty for GM crops, the focus groups predicted that survey respondents planned to increase the share of soybean acreage in GM herbicide-resistant soybeans. The increase was significant at the 90 percent level. Total intended acres in GM soybeans, however, declined by 9,130 acres. The mean of each respondent's share of soybean acres in RR soybeans was significantly higher, at the 90 percent level, in 2000 relative to 1999. This provided statistical support for the focus-group finding that production advantages dominated any negative effect of price uncertainty for GM soybeans in respondents' 2000 planting intentions. Table 2 reports 1999 acreage shares and intended 2000 acreage shares in GM crops for the total sample and for individual respondents. Each row corresponds to a specific GM trait.

Table 2. Shares in Genetically Modified Crops: 1999 Acreage and Intended 2000 Acreage

	1999	2000 (intended)
Share of total sample soybean acreage in RR	60.55	66.10
Mean of each individual farmer's share of soybean acres in RR	61.44	63.58
Share of total sample corn acreage in Bt	30.67	28.60
Mean of each individual farmer's share of corn acres in Bt	25.44	23.65
Share of total sample corn acreage in LL	3.43	3.43
Mean of each individual farmer's share of corn acres in LL	3.24	3.58
Share of total sample corn acreage in RR	1.50	1.40
Mean of each individual farmer's share of corn acres in RR	1.96	2.00

Table 3. **Percentage of Farmers Who Grew Corn with Specified Traits -**

Trait	1997	1998	1999	1997–1999	2000 -
High Oil	4.9	7.7	11.3	12.3	4.9
White	0.8	0.8	2.1	2.1	1.0
Other Value Added	2.6	3.3	4.4	4.6	3.9
Bt	21.8	45.2	53.7	60.9	40.9
RR	0.0	4.9	8.7	12.3	4.4
LL	3.1	9.3	8.7	14.9	8.0
CLEARFIELD (IMI)	4.4	6.2	6.7	10.3	6.4
Stacked	0.8	3.1	3.1	5.1	3.9

Respondents planned to decrease acreage in GM corn. The decrease was significant at the 90 percent level for Bt corn but was not significant for herbicide-tolerant corn (Table 2). While 60.6 percent of respondents planted Bt corn in 1999, only 49.9 percent intended to plant Bt corn in 2000. The mean of the share of individuals' acreage in Bt corn was lower in 2000 than 1999, and the difference was significant at the 90 percent level. Intended 2000 acreage planted to herbicide-tolerant corn varieties remained essentially unchanged from 1999 planted acres. Only 18 percent of respondents planted herbicide-tolerant corn in 1999, and only 13 percent intended to do so in 2000. There was no significant difference in mean of the share of individuals' acreage in herbicide-tolerant corn between 1999 and 2000.

For corn, we asked farmers to indicate whether they had grown corn with certain traits for each year from 1997–1999 and their intentions for 2000. These planting histories are summarized in Table 3. Each row is a specific trait. Each column reports the percentage of respondents who grew corn with that trait for the year specified at the top of that column. The fifth column (1997–1999) reports the percentage of respondents who planted the specified trait in one or more of the years 1997–1999. Comparing this column to the individual years, there was clearly some experimentation with specialized traits that did not induce the producer to continue them. With the exception of Bt corn, relatively few producers had experimented with each of the other cost-reducing traits or intended to plant them in 2000. For all specialized traits, fewer respondents intended to plant the trait in 2000 than had planted it in 1999 although in some cases the decline was very small. The decline was most striking for high-oil corn. The percentage of growers who intended to plant high-oil corn in 2000 declined to its 1997 level.

Farm and Farmer Characteristics

The average respondent was 54 years old and had 32 years of farming experience. Consistent with national and statewide patterns, our sample had a relatively large share of older farmers and more experienced farmers. The average respondent operated a 560-acre farm and owned approximately half his acreage.

Farming was the primary occupation of 84 percent of the operators in the sample. The median education level was some study at the college level but no college degree. Figure 1 reports the distribution of educational attainment. The median respondent had a gross farm income of $50,000–$99,999. In Figure 2, we report the distribution of 1999 gross farm income.

Livestock was part of the farm operation of 61 percent of survey respondents. Within this 61 percent, the frequency of different types of livestock operations varied as shown in Figure 3. Cow/calf operations were the most common. Fifty-seven percent of respondents with livestock reported cow/calf operations as part of their livestock activities. Cattle feedlots were operated by 37.6 percent of respondents with livestock. Hog-finishing operations were operated by 35 percent of respondents with livestock. Hog farrowing was reported by 18.6 percent of respondents with livestock. Only 12 percent had diary operations. Sheep, poultry, and other livestock were reported by only very small shares of respondents.

Figure 1. **Respondent Education**

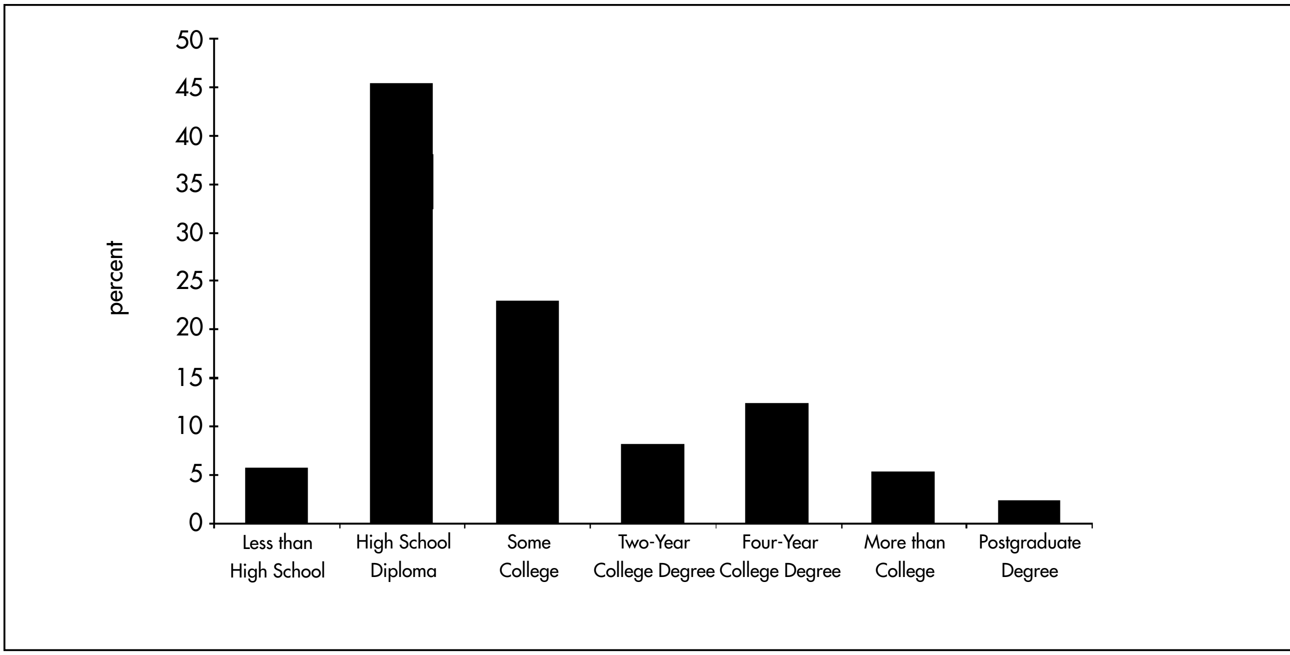
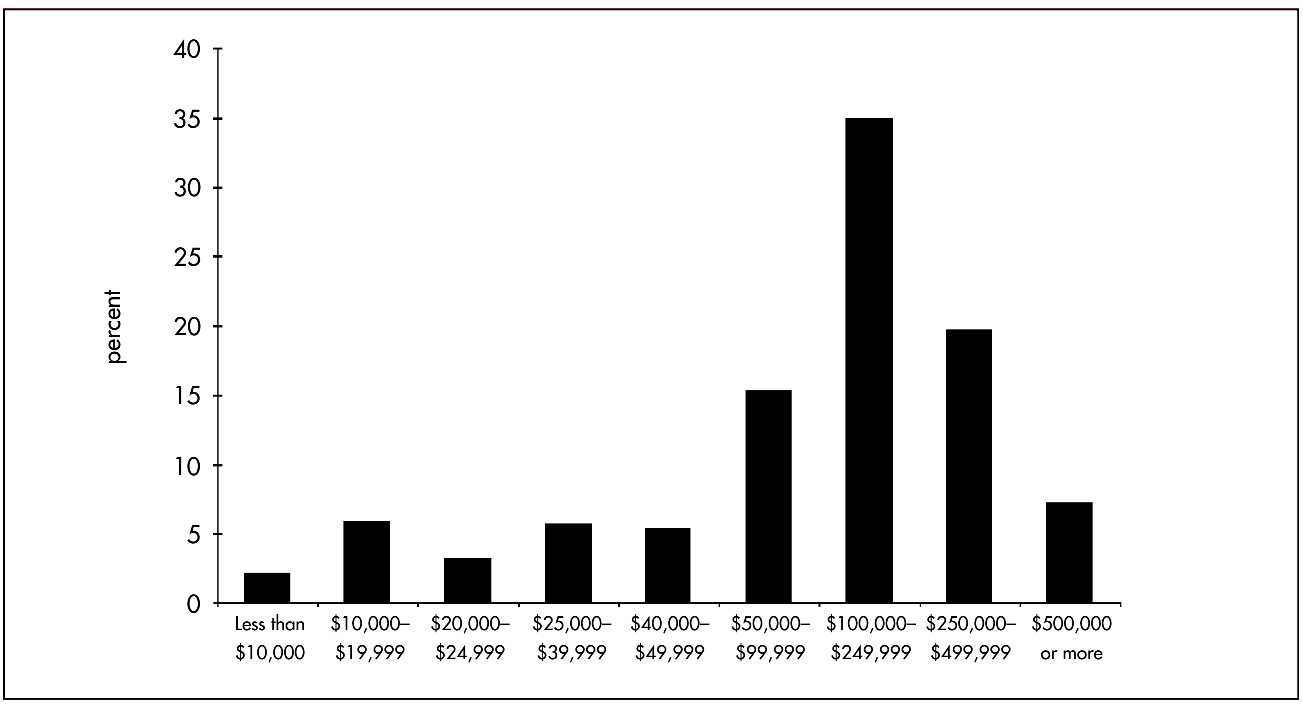
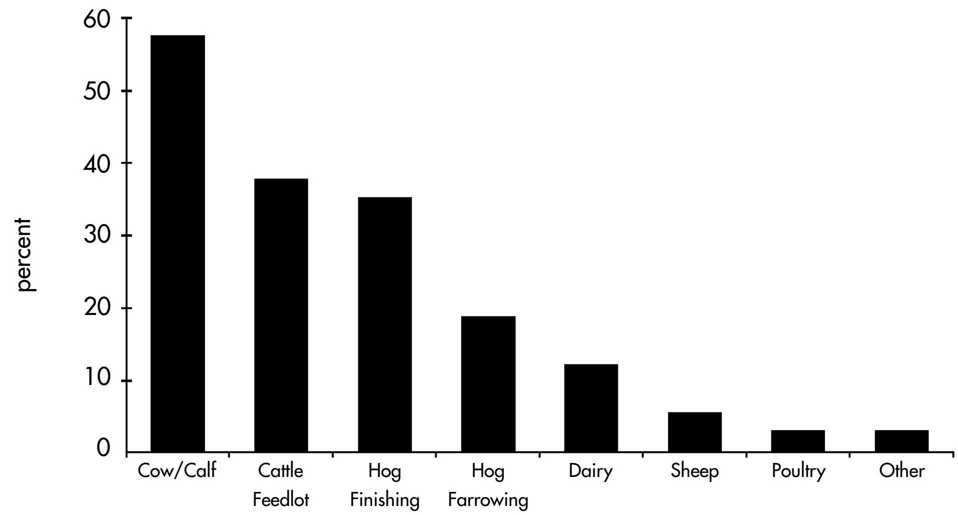


Figure 2. **Respondent Gross Farm Income -**



Many farm and operator characteristics were significantly correlated in our sample. Generally, these correlations were consistent with evidence from the adoption literature and with casual observation. Operator age and years of farming experience were positively and significantly correlated. Older farmers tended to have less schooling as shown by a significant negative correlation between age and years of schooling. Years of schooling and share of acreage owned were significantly negatively correlated while years of schooling and total acreage operated were significantly positively correlated. These relationships were

Figure 3. **Livestock Operations: Share of Each Type among Respondents Reporting Any Livestock**



consistent with observed patterns in the Midwest: Younger farmers tend to operate larger farms, and own a smaller share of their farms than older farmers do. Consistent with their relationship to farm size, age and experience were significantly and negatively correlated with gross farm income.

The relationship between farmer education and farm characteristics was more complex. While more years of formal education had a significant positive correlation with gross farm income, full-time farmers had significantly less formal education than part-time farmers did. Simultaneously, as expected, full-time farmers had significantly higher gross farm incomes. However, given that there was no significant correlation between years of formal education and full-time farming, these relationships appear to be consistent with the significant negative correlation between age and schooling identified earlier. Alexander, Fernandez-Cornejo, and Goodhue evaluate relationships between these farm and farmer characteristics and the farmer's use of GM varieties.

Producer Attitudes

In order to capture producer risk preferences, we included three attitudinal questions developed by Barham. Respondents were asked to strongly agree, somewhat agree, neither agree nor disagree, somewhat

Table 4. **Risk Attitudes**

	Percentage of Respondents				
Statement	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
"I would rather take more of a chance on a big profit than be content with a smaller but less risky profit."	10.4	19.3	31.5	31.5	7.4
"I regard myself as the kind of person who is willing to take more risk than the average farmer."	5.7	21.7	33.6	32.7	6.3
"Farmers who are willing to take chances usually do better financially."	9.8	18.9	36.4	30.5	4.4

disagree, or strongly disagree to the following statements about risk: (1) "I would rather take more of a chance on making a big profit than be content with a smaller but less risky profit." (2) "I regard myself as the kind of person who is willing to take more risks than the average farmer." (3) "Farmers who are willing to take chances usually do better financially." Table 4 reports the percentage of respondents for each possible answer. For example, the first entry in the first row of the table indicates that 10.4 percent of respondents strongly disagreed with the statement "I would rather take more of a chance on a big profit than be content with a smaller but less risky profit." As summarized in Table 4, responses to the three risk questions were largely consistent with each other for the sample as a whole. That is, the percentage of respondents in each response category was roughly the same across questions as can be seen by reading down each column in Table 4. For example, for the three questions, 10.4 percent, 5.7 percent, and 9.8 percent of respondents strongly disagreed. Responses were largely consistent for individual responses as well.

To elicit their perception of consumer acceptance of biotechnology food products, respondents were asked to agree or disagree based on the above scale with the following statement (also developed by Barham): "Consumers will not accept some food products from biotechnology." Responses to this statement are summarized in Table 5. Each entry provides the percentage of respondents in the corresponding response category. For example, the first entry reports that 3.0 percent of respondents strongly disagreed with the statement.

Table 5. **Percentage of Respondents' Agreement with the Statement "*Consumers will not accept some genetically modified foods*"**

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
3.0	9.8	22.9	49.0	15.4

We evaluated the relationship between respondents' answers to these attitudinal questions and their plantings of GM varieties. Farmers were separated into four adoption categories based on their 1999 plantings and 2000 planting intentions: (1) a *GM* group who grew GM varieties in 1999 and planned to continue growing GM varieties in 2000, (2) a *conventional only* group who did not grow GM varieties in 1999 and planned to grow only conventional varieties in 2000, (3) a *disadopters* group who planned to disadopt GM varieties in 2000, and (4) an *adopters* group who planned to adopt GM varieties in 2000.

We applied these adoption categories separately for corn and soybeans because farmers' behavior differed across crops for just over a quarter of the sample. Overall, for the 2000 crop year planting intentions, farmers were more likely to reduce acreage or disadopt GM corn than GM soybeans. In fact, many producers increased their planned acreage allocation of GM soybeans while simultaneously decreasing their acreage allocation of GM corn.

Tables 6 through 9 report these results. The tables summarize responses to a single risk-attitude question for a single crop by adoption category. Within each category, respondents are grouped by their degree of agreement (left) or disagreement (right) with the question. Within each category, percentages are reported so that each row adds up to 100 percent of the respondents in that adoption category, subject to rounding. For example, the first row in Table 6 reports results for respondents who planted GM corn in 1999 and intended to do so in 2000. The statement "I would rather take more of a chance on a big profit than be content with a smaller but less risky profit" generated strong disagreement by 7.1 percent of respondents. The table facilitates comparing this share with the share of respondents who disagree in other adoption categories: none of corn producers who planned to adopt GM corn in 2000 strongly disagreed with the statement as shown by the second row. For each question, agreement with the statement suggests that the respondent is less risk-averse than disagreement with the statement does.

As demonstrated in the tables, producer responses to questions regarding risk did not differ substantially across adoption categories. The one notable exception is that intended 2000 adopters of GM soybeans appeared to be more risk-averse than producers in all other categories. Within each adoption category, producers' agreement or disagreement with each of the three risk questions was approximately the same although the intensity may have differed.

Table 9 reports consumer-acceptance responses by crop and adoption category using the same structure as the tables reporting the responses to risk-attitude questions. While there was relatively little variation across groups, again, the one group that was differentiated is 2000 adopters of GM soybeans. The 2000 adopters of GM soybeans expressed *stronger* agreement with the statement that "consumers will not accept some food products from biotechnology" than producers in all other groups expressed. Combining these two findings regarding new adopters of GM soybeans suggests that other risks and returns are driving the adoption decision rather than risks due to the GM controversy.

Table 6. **Percent of Respondents' Agreement with the Statement "*I would rather take more of a chance on making a big profit than be content with a smaller but less risky profit*" by Corn and Soybean Adoption Category**

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree -
GM Corn Use -					
Use Both Years	7.1	33.3	32.8	19.7	7.1
Adopt 2000	0.0	40.0	30.0	20.0	10.0
Disadopt 2000	7.8	25.5	35.3	21.6	9.8
Use Neither Year	8.6	30.1	26.9	17.2	17.2
GM Soybean Use -					
100% Use Both Years	7.5	30.1	32.9	17.1	12.3
Use Both Years	9.0	35.8	25.4	23.9	6.0
Adopt 2000	0.0	18.8	56.3	18.8	6.3
Disadopt 2000	6.5	22.6	29.0	29.0	12.9
Use Neither Year	9.4	34.0	30.2	13.2	13.2

Table 7. **Percent of Respondents' Agreement with the Statement "*I regard myself as the kind of person who is willing to take more risk than the average farmer*" by Corn and Soybean Adoption Category**

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree -
GM Corn Use -					
Use Both Years	8.2	40.1	27.5	20.9	4.3
Adopt 2000	0.0	30.0	30.0	30.0	10.0
Disadopt 2000	5.9	25.5	41.2	25.5	2.0
Use Neither Year	3.2	22.6	41.9	20.4	11.8
GM Soybean Use -					
100% Use Both Years	7.5	33.6	30.8	22.6	5.5
Use Both Years	7.5	34.3	32.8	19.4	6.0
Adopt 2000	0.0	25.0	37.5	31.3	6.3
Disadopt 2000	6.5	29.0	35.5	22.6	6.5
Use Neither Year	9.4	28.3	39.6	17.0	5.7

Table 8. **Percent of Respondents' Agreement with the Statement "*Farmers who are willing to take chances usually do better financially*" by Corn and Soybean Adoption Category**

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree -
GM Corn Use -					
Use Both Years	4.4	35.5	38.3	16.4	5.5
Adopt 2000	0.0	40.0	50.0	10.0	0.0
Disadopt 2000	7.8	25.5	27.5	23.5	15.7
Use Neither Year	3.2	22.3	36.2	22.3	16.0
GM Soybean Use -					
100% Use Both Years	5.5	30.1	39.0	15.8	9.6
Use Both Years	4.5	30.1	39.0	15.8	9.6
Adopt 2000	4.5	34.3	41.8	16.4	3.0
Disadopt 2000	3.2	32.3	22.6	19.4	22.6
Use Neither Year	7.6	24.5	45.3	15.1	7.6

Table 9. **Percent of Respondents' Agreement with the Statement "*Consumers will not accept some genetically modified foods*" by Corn and Soybean Adoption Category**

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
GM Corn Use					
Use Both Years	11.5	49.2	25.1	10.9	3.3
Adopt 2000	30.0	40.0	10.0	20.0	0.0
Disadopt 2000	11.8	52.9	21.6	9.8	3.9
Use Neither Year	23.7	47.3	20.4	0.5	2.2
GM Soybean Use					
100% Use Both Years	13.7	50.7	24.7	8.9	2.1
Use Both Years	13.4	50.8	23.9	9.0	3.0
Adopt 2000	25.0	62.5	6.3	6.3	0.0
Disadopt 2000	22.6	48.4	19.4	9.7	0.0
Use Neither Year	24.5	35.9	24.5	11.3	3.8

THEORETICAL MODEL

In this section, we model the GM-conventional variety acreage-allocation decision as an expected utility maximization problem for a risk-averse producer. We demonstrate that it may be optimal for a risk-averse producer to reduce his GM corn as a share of his corn acreage and continue to plant most of his soybean acreage in GM soybeans. This outcome is due to the mean and variance properties of GM varieties relative to the conventional ones. The outcome is also consistent with the behavior of a risk-neutral producer.

Both GM and conventional varieties have stochastic yields. The GM crop has an additional price risk relative to the conventional variety. We do not model commodity price risk, or correlated yield risk across GM and conventional varieties, for two reasons. First, adding covariances across varieties would substantially complicate our theoretical analysis without substantially contributing to our understanding of the factors driving the acreage-allocation decision. Second, in practice producers have a number of tools at their disposal for managing commodity risk. We emphasize the relative risk of GM and conventional varieties, not the risk of the commodity.

Both existing economic studies and producer comments from our focus groups support the modeling of risk-averse, rather than risk-neutral, producers. Empirical studies have established that producer risk aversion is an important factor in acreage-allocation decisions using producer-level data (Marra and Carlson). Other studies have used aggregate data to investigate the role of producer risk aversion in supply response (Just; Chavas and Holt 1990, 1996). In the focus groups, several producers said that they plant Bt corn because it is "good insurance" (see *Focus Groups*). Other producers expressed concern about price risk associated with the market for GM crops. Some acted on this concern. One producer exchanged all his GM seed for conventional seed just before planting in 1999 solely because of market uncertainty. In addition, at least one producer in each meeting had asked for a written guarantee that their local elevator would purchase GM crops harvested in fall 2000. No such guarantee was ever provided.

Producer acreage allocations can be modeled as a function of other explanations, such as land heterogeneity and grower heterogeneity. Cropland varies by soil quality and by the length of the growing season. Fields in southern Iowa mature earlier, and are more susceptible to the European corn borer than fields planted at the same time in northern Iowa. In northern Iowa, fields that are planted relatively early are more susceptible to the corn borer than fields that are planted later. The benefit of adopting GM crops may vary with a farmer's management ability; Bt varieties eliminate the need to scout fields for corn borers and determine when spraying is justified financially.

Our approach is based on the model of a risk-averse firm developed by Sandmo and extended for acreage-allocation decisions by Just and Zilberman (1983, 1984). The producer maximizes the expected utility of his end-of-period wealth by choosing the acreage he plants in the conventional and GM varieties (A_c and A_{gm}). Since the producer is risk-averse, $U'[W] > 0$ and $U''[W] < 0$. We decompose wealth into total land value, $P_l\bar{A}$, and net returns, i.e., production costs, pest-control costs, output price, and yield. We separate pest-control costs from other production costs because GM input traits affect the producer's pest-control options. Wealth is defined as

$$W = P_l\bar{A} + (PY_c - C_c - Z_c)A_c + ((P-d)Y_{gm} - C_{gm} - Z_{gm})A_{gm} \quad (4.1)$$

We use the following notation: The yield of the conventional variety is $Y_c \sim (\bar{Y}_c, \sigma^2_{Y_c})$; the yield of the GM variety is $Y_{gm} \sim (\bar{Y}_{gm}, \sigma^2_{Y_{gm}})$; C_c is certain production costs for the conventional variety; C_{gm} is certain production costs for the GM variety; the pest-control cost associated with the conventional variety is $Z_c \sim (\bar{Z}_c, \sigma^2_{Z_c})$; the pest-control cost associated with the GM variety is $Z_{gm} \sim (\bar{Z}_{gm}, \sigma^2_{Z_{gm}})$; and P is output price. We assume that pest-control costs are independent of each other and of yields: $cov(Z_{gm}, Z_c) = 0$, $cov(Y_{gm}, Z_{gm}) = 0$, and $cov(Y_c, Z_c) = 0$. The uncertain output price penalty on GM crops is denoted by $d \sim (\bar{d}, \sigma^2_d), 0 \geq \bar{d} \geq P$. We assume that the price discount on GM crops is independent of the per-acre yield of GM crops or $Cov(d, Y_{gm}) = 0$.[4] The producer's maximization problem is now the following:

$$\max \quad EU\left[P_l\bar{A} + (PY_c - C_c - Z_c)A_c \quad (4.2)\right.$$
$$\left. + ((P-d)Y_{gm} - C_{gm} - Z_{gm})A_{gm}\right]$$
$$s.t. A_c \geq 0, A_{gm} \geq 0, A_c + A_{gm} \leq \bar{A}.$$

Solving the maximization problem yields three possible solutions: an interior solution, where the producer plants both varieties, and two corner solutions, where the producer plants only one variety.

Proposition 1. *When the producer plants both crops, then the acreage allocation is*

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

Proofs are in Appendix D. The acreage in the conventional crop will increase as the expected returns for the conventional crop increase relative to the expected returns for the GM crop and as the variance of the GM crop increases relative to the variance of the conventional crop. The acreage in the GM crop will increase as the expected returns for the GM crop increase relative to the expected returns for the conventional crop and as the variance of the conventional crop increases relative to the variance of the GM crop.

Proposition 2. *Necessary conditions for the producer to plant a single crop are:*
A. The producer will plant all the acreage in the GM crop if
$ER_{gm} \geq ER_c + \phi\bar{A}\,var(gm)$.
B. The producer will plant all his acreage in the conventional crop if
$ER_c \geq ER_{gm} + \phi\bar{A}\,var(c)$.

The intuition underlying the proof is apparent from the expressions in Proposition 1. The summary of crop attributes in Table 1 suggests that we are more likely to observe corner solutions where producers plant 100 percent RR soybeans than corner solutions where producers plant 100 percent conventional soybeans. We are more likely to observe corner solutions where producers plant 100 percent conventional corn than corner solutions where producers plant 100 percent Bt corn. Based on producers' focus-group characterizations of RR soybeans, we define a stronger set of sufficient conditions. These conditions identify when the production characteristics of the GM crop will dominate the price risk due to the GM controversy.

Proposition 3. *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.*

The comparative statics predictions of our model follow those of the standard two-crop acreage-allocation problem although our focus on expected pest-control costs and relative price risk leads us to emphasize different results. The producer will allocate less acreage to a crop if its expected pest-control costs increase. The producer will allocate less acreage to a crop if there is an increase in the variance of either yield variance or pest-control costs. While an increase in the expected yield of the conventional variety unambiguously increases its acreage, the GM variety's price risk results in an ambiguous sign for the effect of an increase in expected GM variety yield on GM acreage. However, if the price discount was known for certain, GM acreage would increase with expected GM yield.

A producer's acreage allocation is dependent on his risk preferences. A more risk-averse producer will have the same allocation as a less risk-averse producer if the shares of total profit variance are equal across varieties. A more risk-averse producer will have a relatively larger share of acreage in the GM (conventional) crop if the GM (conventional) crop accounts for a smaller share of total profit variance than the conventional (GM) crop does.

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. This results in a prediction regarding the effect of the GM controversy on 2000 planting decisions relative to 1999 planting decisions. For producers who planted both types in 1999, we predict that they will reduce the acreage shares in GM crops due to the increased price uncertainty. Based on the propositions and comparative statics results, we develop six testable

[4] This assumption is justified because the price penalty for GM crops is due to a demand shock. Furthermore, since the individual producer is a price taker, the individual producer's average yield will be uncorrelated with the market-determined price penalty.

hypotheses that examine the acreage-allocation effect of an increase in output price risk for the GM crop relative to the conventional crop. Each of these hypotheses is a means of testing the effect of the GM controversy on producers' 2000 acreage-allocation decisions relative to their 1999 decisions. Accepting a hypothesis indicates that the GM controversy and its associated price risk dominated any offsetting production considerations in producers' acreage-allocation decisions.

Testable Hypothesis 1 (TH1). *Producers who planted both GM and conventional varieties in 1999 will have a smaller share of acres in GM varieties in 2000, ceteris paribus.*

A risk-averse producer will change his acreage allocation in response to a change in the share of the total profit variance attributable to each crop at his initial (1999) allocation. The producer will decrease his acreage in the GM crop if its effect on the variance in profits increases relative to that of the conventional crop. With the increased profit variance associated with the GM crop in 2000, TH1 predicts that risk-averse producers with an interior solution in 1999 would reduce the share of GM acreage in both corn and soybeans assuming that risk preferences are independent of the crop. Based on the focus-group findings, 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.

Testable Hypothesis 2 (TH2). *Producers' changes in acreage allocations from 1999 to 2000 will be positively correlated.*

Both the direction and the magnitude of the changes in producers' acreage allocations depend on their degree of risk aversion, which is independent of the crop. TH2 applies to producers at an interior solution.

Many survey respondents were at corner solutions in 1999 and planted only conventional or GM varieties for at least one crop. Testable hypotheses regarding corner solutions are highly sensitive to small perturbations that we do not capture in our data. We offer two hypotheses regarding corner solutions.

Testable Hypothesis 3 (TH3). *Producers who planted only conventional varieties in 1999 will continue to do so in 2000.*

TH3 only applies to producers at a corner solution in 1999. This hypothesis would be accepted if the price uncertainty associated with GM varieties offset any new production-cost considerations that would suggest increasing GM acres. In contrast, if this hypothesis is rejected, it provides support for the hypothesis that there is no net effect of price uncertainty due to the GM controversy on producer's acreage-allocation decisions given production cost considerations.

Based on the theoretical model and the focus-group results, we hypothesize that producers' acreage allocations will depend on their risk preferences and their beliefs about the possible price penalty for GM crops and that producers who are more risk-averse are less likely to plant GM crops. This prediction is summarized in Hypotheses 1–3 and also based on the focus-group results. Many survey respondents planted 100 percent GM soybeans in 1999. For these individuals, the possibility of a price penalty for the 2000 crop will not necessarily affect their 2000 acreage-allocation decision but will depend on the "stickiness" of the corner solution, which depends on risk preferences and the price penalty. What we can predict is that *no more* producers will choose to plant 100 percent GM soybeans if the GM controversy is an important consideration.

Testable Hypothesis 4 (TH4). *Only producers who planted GM soybeans in 1999 will plant 100 percent GM soybeans in 2000.*

Two more predictions follow from the comparative static result that producers who expect a smaller price discount for GM crops will be more likely to plant GM crops. There are two farm characteristics that could result in a smaller expected price discount. First, a producer who feeds all of his corn to livestock will never face a market price for corn and, therefore, has an expected price penalty of zero.[5] Second, a producer who has substantial on-farm storage relative to his total production will be less vulnerable in the event that elevators delay acceptance of GM crops. On-farm storage provides marketing flexibility, allowing the

[5] Although this is currently true, it will remain true only as long as there is no price penalty for livestock raised on GM crops.

producer additional time to find elevators or livestock operations to purchase GM corn.

Testable Hypothesis 5 (TH5). *Producers who raise livestock will be less likely to reduce the share of their GM corn acreage. GM soybean acreage will be unaffected.*

Testable Hypothesis 6 (TH6). *Producers who expect to store a larger portion of their crop on-farm will be less likely to reduce the share of their GM crop acreage.*

While our theoretical model has focused on risk-averse producers, the role of risk in acreage-allocation decisions is controversial, especially for producers in developed countries, who are sometimes thought to be risk-neutral. Our testable hypotheses would sometimes be supported by the behavior of a risk-neutral producer. In contrast to a risk-averse producer, a risk-neutral producer will always plant all his acreage in the variety with the higher expected return in our model setting of homogeneous land. A risk-neutral producer maximizing expected returns with heterogeneous land will allocate acreage based on the highest expected return for each field's land quality. Hence, in the 2000 crop year, if the expected return for the GM crop with the discount is higher than the expected return for the conventional crop, the producer will plant the GM crop. The added variability due to the possibility of the penalty does not enter into the decision. This suggests that, if the expected return from the GM crop is higher, even with an expected price penalty, risk-neutral producers will not respond to the GM controversy by adjusting their acreage allocation other than relatively minor changes due to heterogeneity considerations. In that case, we would not expect Hypotheses 1–6 to hold for risk-neutral producers. On the other hand, if the expected price penalty is relatively large, then a risk-neutral producer will respond to the GM controversy in the same qualitative manner as a risk-averse producer. In that case, we predict that Hypotheses 1–6 would hold for risk-neutral producers if a price penalty for GM crops is the dominant factor governing acreage-allocation decisions. We examine the role of other explanations of acreage-allocation decisions in our empirical analysis, such as the presence of a management or labor constraint and manager ability.

Since our testable hypotheses, alone, do not allow us to conclude whether producers are risk-averse, we use responses to survey questions regarding risk to examine whether risk attitudes influence acreage allocation. The specific characteristics of the problem we examine are biased against finding risk aversion to be significant. Since we expect production characteristics to dominate risk considerations for GM soybeans, we would not expect to find risk aversion to be a significant explanatory factor for soybean acreage-allocation decisions. Even if producers were risk-averse, we would only expect risk aversion to be a significant explanatory factor for corn acreage-allocation decisions.

EMPIRICAL ANALYSIS

In our empirical analysis, we focused on two questions. First, we addressed whether farmers' planting intentions for 2000 were consistent with predictions from our focus-group results (see Table 1). As predicted, survey respondents planned to increase acreage in GM soybeans and the increase was significant at the 90 percent level. Respondents planned to decrease acreage in GM corn, and the decrease was significant at the 90 percent level for Bt corn but not significant for herbicide-tolerant corn. These findings are consistent with the dynamic diffusion analysis of national data for corn, soybeans, and other GM crops in Fernandez-Cornejo, Alexander, and Goodhue. Second, we test the hypotheses generated by the theoretical model regarding the impact of price uncertainty due to the GM controversy on producers' planting decisions. The empirical results suggest that the GM controversy affected farmers' planting decisions for GM corn but not for GM soybeans. The primary factors affecting the 2000 share of GM corn were the share in 1999 and the degree of concern regarding yield damage from the European corn borer. Agreement with the statement that farmers would benefit from biotechnology was associated with an increase in the share of GM corn acres, and agreement with the statement that consumers will not accept some food products from biotechnology was associated with a decline in the share of GM corn acres. For GM soybeans, the primary predictor of the 2000 share of GM soybeans was the share in 1999. Agreement with the statement that farmers would benefit from biotechnology has a positive effect on the 2000 share, and farm size, as measured by 1999 gross farm income, also has a positive effect. In the full sample analysis, years of schooling had a negative effect.

While the survey included questions regarding varieties with output-enhancing traits, so few respondents planted these varieties that we could not conduct a statistical analysis. Alexander, Fernandez-Cornejo, and Goodhue discuss some of the causes of this limited adoption for the specific case of high-oil corn.

Regression Analysis

Behavior within a Crop

TH1 predicted that producers at an interior solution would decrease their share of GM acreage. The null hypothesis is that producers initially at an interior solution did not reduce their GM acreage: $H_0 : \beta_{GM99} \geq 1$, $H_A : \beta_{GM99} < 1$. We regressed the 2000 share of each GM crop on its 1999 share. Table 10 reports results that were consistent with the focus-group results and the simple statistics presented above. Producers planned to increase their share of GM soybeans, which suggests that the GM controversy was not a factor in producers' soybean acreage-allocation decisions.

Producers did reduce their intended GM corn acreage, which is consistent with the predicted response to the GM controversy. This response can not distinguish between risk aversion and risk neutrality because we could not identify whether it was motivated by an increase in expected price variance or a decrease in

Table 10. **Tobit Regressions of Intended 2000 Share of GM Soybean Acreage on the 1999 Share of GM Soybean Acreage and Intended 2000 Share of GM Corn Acreage on the 1999 Share of GM Corn Acreage for Producers Who Were at an Interior Solution in 1999**

	Intended Share GM Soybeans 2000	Intended Share GM Corn 2000
Share GM Soybeans 1999	1.251476	
111 Observations – Standard Error	(0.0934006)	
95 Percent Confidence Interval	[1.0662485, 1.436468]	
Share GM Corn 1999		0.852921
201 Observations – Standard Error		(0.0470728)
95 Percent Confidence Interval		[0.7601253, 0.9457167]

the expected price of GM crops. We found that, as predicted by TH1, producers at an interior solution in 1999 planned to reduce their GM corn acreage in 2000 ($\beta_{GM99} < 1$ at the 99 percent level).

Behavior across Crops

TH2 predicted that there will be a positive relationship between the change in share of corn and soybeans in GM acreage between 1999 and 2000. Rejecting TH2 in favor of a negative relationship in the acreage response for corn and soybeans would be consistent with the previous finding that producers had a different acreage response to the controversy for GM corn and GM soybeans.

Our results regarding TH2 are reported in Table 11. Based on the confidence intervals, the hypothesis is not supported, although there is a weakly positive relationship for 1999 interior solution farmers. There are at least three possible explanations for this finding. First, farmers' risk preferences may vary by crop. Second, farmers' expectations for the GM price discounts may vary by crop. Third, production cost considerations may have different effects by crop. Note that neither rejection nor acceptance of TH2 allowed us to determine whether producers were risk-averse or risk-neutral.

Corner Solutions

TH3 predicted that producers who planted only conventional seed in 1999 would intend to plant only conventional seed in 2000. We rejected TH3. For soybeans, of the 71 producers who planted 100 percent conventional in 1999, sixteen intended to plant at least some GM soybeans in 2000. For corn, of the 108 producers who planted 100 percent conventional in 1999, thirteen intended to plant at least some GM corn in 2000.

TH4 predicted that, given the price risk associated with GM crops in 2000, no more producers will plant 100 percent GM in 2000 than 1999. We rejected TH4. Thirty-eight of 187 farmers who planted less than 100 percent GM soybeans in 1999 intended to plant 100 percent GM soybeans in 2000. Six of 304 farmers who planted less than 100 percent GM corn in 1999 intended to plant 100 percent GM corn in 2000. The rejections of TH3 and TH4 indicate that the GM controversy was not the only factor influencing changes in acreage-allocation decisions between 1999 and 2000.

Factors That Influenced 2000 Planting Intentions

Tables 12 and 13 report our results regarding the determinants of 2000 planting intentions. We report results from a two-limit Tobit model for each crop for two data samples: the entire sample and the subset of respondents who planted both GM and non-GM varieties in 1999. We report the subset in order to facilitate comparison of the determinants of planting intentions with the findings regarding TH1 reported above. We use a two-limit Tobit model because we use the share of acreage planted in GM varieties as our dependent variable.

The 1999 acreage shares were the most important determinant of 2000 acreage shares for both corn and soybeans. The 1999 acreage shares are a measure of past experience, which in turn is a function of information,

Table 11. Ordinary Least Squares (OLS) Regressions of Percent Change GM Corn Acreage on Percent Change GM Soybean Acreage

	Percent Change GM Corn Full Sample	Percent Change GM Corn Subsample: Interior in 1999
Percent Change GM Soybean Acreage	0.0601467	0.1921725[a]
Standard Error (Absolute Value t Statistic)	0.0676183	0.1042134
95 Percent Confidence Interval	−0.0728535 0.1931468	−0.0160178 0.4003628
Observations	343	65
R^2	0.0023	0.0505

[a] Significant at 90 percent level.

farmer habits, and other farmer characteristics. In addition, one would expect the previous year's acreage share to have greater predictive power the closer producers were to their adoption ceiling. The regression results support the hypothesis that farmers were near their diffusion ceilings for these crops (Fernandez-Cornejo, Alexander, and Goodhue). -

For GM corn, the intended 2000 share was also explained by the farmer's attitudes, the number of crop operations, some livestock operations, and farm size.

Table 12. **Tobit Regressions on Intended 2000 GM Corn Acreage Share: Farmers at the Interior in 1999 and Full Sample**

	Subsample: Interior in 1999 Intended 2000 Share GM Corn		Full Sample Intended 2000 Share GM Corn	
	Tobit Regression	Absolute Value t Statistic	Tobit Regression	Absolute Value t Statistic
Share GM corn – 1999	0.894[a]	(9.52)	1.270[a]	(15.38)
Total corn acreage – 2000 (1,000s)	−0.013	(1.38)	−0.023[b]	(2.21)
Agree willing to take risks	0.056[c]	(1.80)	0.032	(1.07)
Agree farmers will benefit from biotechnology	0.075[b]	(2.26)	0.057[c]	(1.73)
Agree consumers will not accept biotech food products	−0.045[b]	(2.14)	−0.051[b]	(2.38)
Concern: Yield damage from European corn borer	0.089[a]	(3.72)	0.070[a]	(2.91)
Number of crops	0.058[c]	(1.84)	0.064[b]	(1.98)
1999 gross farm income ($100,000s)	0.043[b]	(2.29)	0.060[a]	(3.09)
Value of farmland ($100,000s)	−0.002	(0.72)	0.002	(0.52)
Years of school	0.003	(0.25)	−0.005	(0.49)
Cow/calf operation	−0.055	(0.89)	−0.076	(1.23)
Hog farrowing operation	−0.025	(0.32)	−0.027	(0.35)
Hog finishing operation	−0.114[c]	(1.84)	−0.078	(1.23)
Other livestock	−0.297	(1.46)	−0.440[c]	(1.94)
Corn yield test district 2	−0.077	(0.88)	−0.079	(0.84)
Corn yield test district 3	−0.041	(0.58)	0.035	(0.47)
Corn yield test district 4	0.088	(0.89)	0.078	(0.78)
Corn yield test district 5	0.033	(0.43)	0.015	(0.19)
Corn yield test district 6	0.072	(0.72)	0.060	(0.58)
Corn yield test district 7	−0.076	(0.67)	−0.041	(0.35)
On-farm storage (10,000 bushels)	0.002	(0.28)	0.001	(0.08)
Constant	−0.253	(1.34)	−0.355	(1.93)
Observations	199		313	
Pseudo R^2	0.560		0.570	

[a] Significant at 99 percent. [b] Significant at 95 percent. [c] Significant at 90 percent.

Table 13. **Tobit Regressions on Intended 2000 GM Soybean Acreage Share: Farmers at the Interior in 1999 and Full Sample[a]**

	Subsample: Interior in 1999 Intended 2000 Share GM soybeans		Full sample Intended 2000 Share GM soybeans	
	Tobit Regression	**Absolute Value t Statistic**	**Tobit Regression**	**Absolute Value t Statistic**
Share GM soybeans – 1999	1.397[a]	(7.10)	2.117[a]	(10.36)
Total soybean acreage – 2000 (1,000s)	0.006	(0.32)	0.027	(0.90)
Agree willing to take risks	−0.005	(0.09)	−0.062	(0.81)
Agree farmers will benefit from biotechnology	0.117[c]	(1.93)	0.219[b]	(2.56)
Agree consumers will not accept biotech food products	−0.034	(0.80)	−0.029	(0.49)
Number of crops	0.051	(0.83)	0.128	(1.44)
1999 gross farm income ($100,000s)	0.059[c]	(1.62)	0.084[c]	(1.65)
Value of Farmland ($100,000s)	−0.002	(0.36)	−0.003	(0.43)
Years of School	−0.019	(0.92)	−0.096[a]	(3.29)
Cow/calf operation	−0.131	(1.14)	−0.154	(0.92)
Hog farrowing operation	0.137	(0.93)	0.041	(0.19)
Hog finishing operation	0.086	(0.68)	0.214	(1.22)
Other livestock	−0.494	(1.50)	−0.292	(0.59)
On-farm storage (10,000 bushels)	−0.017	(1.27)	−0.032	(1.64)
Southern Iowa dummy	0.131	(1.00)	0.327[c]	(1.75)
Constant	−0.037[c]	(0.12)	0.409	(0.96)
Observations	108		320	
Pseudo R^2	0.33		0.36	

[a] Significant at 99 percent. [b] Significant at 95 percent. [c] Significant at 90 percent.

Farmers who had a high level of concern regarding European corn borer-induced yield damage, or who believed that biotechnology benefited farmers, were significantly more likely to plant GM corn. Farmers who agreed that consumers would not accept some biotech food products were significantly less likely to plant GM corn. This finding suggests that the GM controversy affected the planting of GM corn and is reinforced by the focus-group findings. Risk attitudes had no explanatory power for the full sample and had only a weak effect for the interior sample. This could be because respondents were risk-neutral or because offsetting production risks made it impossible to measure a relationship between risk attitudes and the GM controversy, or because the survey questions were poor measures of risk preferences.

Farm size (as measured by gross farm income) and management requirements (as measured by the number of crop operations) had a positive and significant effect on 2000 GM corn planting intentions. These findings suggest that large farms that are involved in multiple activities are significantly more likely to plant GM crops, which require less management effort. However, the coefficients on livestock operations did not support this hypothesis. The presence of "other livestock" (excluding cow/calf, hog farrowing, and hog finishing) had a negative and weakly significant effect on GM corn 2000 intentions for the full sample, and hog finishing had a negative and weakly significant effect on GM corn 2000 intentions for the interior sample. Wealth did not significantly influence the 2000 share of GM corn in total intended corn acreage.

Land and climate heterogeneity are often thought to influence adoption decisions. Regional dummies, however, proved to have no explanatory power for GM corn. Since climate variations are limited at best, and regional dummies provide only a crude measure of land heterogeneity, this finding was not surprising. (Farm-specific variables, such as primary soil type, were not available for our analysis. Although the survey form (appended) asked farmers to rate the suitability of their farms for corn, too few respondents answered this question for the data to be used.)

For GM soybeans, the 1999 acreage share was the primary explanatory factor. Agreement with the statement that farmers will benefit from biotechnology had a positive effect on the intended 2000 share. Larger farms, as measured by gross farm income, intended to plant a larger share of GM soybeans. However, farm acreage did not have a significant effect. This finding may be due to the rapid adoption of GM soybeans; the adoption of GM soybeans during the study period was beyond the innovator and early adopter stages, which are the most sensitive to farm size (Fernandez-Cornejo, Alexander, and Goodhue). In addition, the farmer's wealth level did not explain the 2000 share of GM soybeans. Risk preferences were not a significant explanatory factor. Two additional variables were significant only in the full sample: The dummy for southern Iowa, which tends to have a more severe weed problem than northern Iowa, was a weakly significant predictor of the intended 2000 share of GM soybeans, and years of schooling had a significant negative effect on the intended 2000 share of GM soybeans.

CONCLUSIONS

Research Findings

We utilized a number of research approaches in order to address our identified research questions: What factors influence the adoption of production cost-reducing and specialized traits by producers, and what effect, if any, did the GM controversy have on producers' adoption decisions for the 2000 crop year? Our findings were consistent across methodologies, which provides us with a greater degree of confidence in our primary results than would be the case if we used a single approach.

According to focus-group participants, the decision to plant specialized traits was highly dependent on market opportunities. Declines in premiums for many value-added traits reduced the profitability of planting these crops. Production difficulties and other factors likely also reduced the attractiveness of planting specialized varieties at least for the specific case of high-oil corn. While many focus-group participants had planted value-added crops, few were intending to do so in 2000. This pattern of behavior was reflected in our survey results. So few respondents planted value-added crops that we were unable to analyze statistically the factors underlying their planting decision. Our results suggest that industry analysts and other observers may wish to reexamine their predictions regarding the adoption of value-added traits in corn and, perhaps, other commodity crops. Unless market conditions change or significantly improved products become commercially available, we are unlikely to see a substantial increase in plantings.

Farmers did not necessarily react to the GM controversy in the same way for corn and soybeans; all permutations of increases and decreases for corn and soybeans were observed for individual survey respondents. The representative farmer increased or held constant his GM soybean acreage but decreased his GM corn acreage, consistent with the dynamic diffusion analysis in Fernandez-Cornejo, Alexander, and Goodhue.

This behavior was consistent with the intentions of focus-group participants, who identified production risks and returns for GM soybeans that offset price risk due to the GM controversy for soybeans. In contrast, production risks and returns for GM corn reinforced this price risk. Further reinforcing these findings, descriptive analysis of our survey data suggested that producers who first adopted GM soybeans in 2000 were both more risk-averse than other growers and agreed more strongly that consumers would not accept some bioengineered foods.

We constructed a theoretical model using the risk and return properties of GM and non-GM crops obtained from the focus groups. The model predicted behavior consistent with the above findings. We then tested it using the survey data. Agreement with the statement that consumers will not accept some bioengineered foods was associated with a significant decline in the intended share of acreage devoted to GM corn but had no explanatory power for GM soybean planting intentions. Risk attitudes did not prove to be a significant explanatory factor, perhaps due to the existence of production risk and price risk, which may have offset each other in the acreage-allocation decision.

Other factors that were found to be significant in determining adoption decisions in our econometric analysis of our survey data included gross farm income, the previous year's acreage allocation, agreement with the statement that farmers will benefit from biotechnology, years of schooling (soybeans only), total corn acreage (corn only), and concern regarding European corn-borer yield damage (corn only). An increase in gross farm income was associated with an increase in the share of GM acreage for both crops as commonly predicted by the adoption literature. The previous year's GM acreage share for that crop was highly significant, consistent with models of the adoption process and our findings from a dynamic diffusion analysis.

For the full corn sample, which included farmers with all or none of their acreage in GM varieties, an increase in total corn acreage was associated with a decrease in the share of corn acreage allocated to GM hybrids. For the full soybean sample, farmers with fewer years of schooling allocated a higher share of acreage to GM soybeans. This is consistent with the observation made by focus-group participants that planting herbicide-resistant soybean varieties reduced management requirements.

Methodological Contribution

In addition to our findings regarding our research questions, our project illustrates the value of focus groups. Our focus groups helped us improve our survey instrument. Beyond this, the participants provided qualitative information regarding the relative risks and returns of GM varieties that would be difficult to obtain using a survey. This information was used in conjunction with our theoretical model to generate testable hypotheses (see *Theoretical Model*) that were tested (see *Empirical Analysis*) using the survey data summarized in the *Survey* section. Our project strongly suggests that focus groups may enhance the research process. In our case, the groups helped us identify testable hypotheses regarding the adoption of GM crops. While we conducted our groups prior to our other activities, focus groups may also be utilized *ex post* to obtain additional information regarding patterns detected in aggregate or survey data.

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APPENDIX A
FOCUS-GROUP SCRIPT

Script in text. Likely responses italicized.

Introduction

- Hello my name is Corinne Alexander and this is my professor Rachael Goodhue. We're both from UC Davis. You may be wondering why it makes sense for people from California to be talking to Iowa farmers, so let me tell you a bit about our background. Rachael and I started on this project because we are looking at how to value input and output traits in seed. We were looking at corn because Rachael's family grows corn here in Iowa. Before I came to grad school, I was working for the Wisconsin Department of Natural Resources, running focus groups on topics like snowmobiling and reformulated gasoline. After looking at the problem for a while, we decided that we should start by talking to the experts—Iowa corn farmers.

  We're interested in how you decide when to plant corn with specialized traits, which traits you choose, and why. As you know, the companies you buy seed from are merging and consolidating at a rapid rate. Pioneer and DuPont finished their merger last month. We're interested in what this means for agriculture—the seed corn market, the fertilizer market, the corn market (No. 2 yellow corn), the high oil corn market. In other words, we want to know things like, will these changes affect the price you pay for seed corn? What is the price you get for high-oil corn? There's a lot of speculation, but no one really knows anything about how farmers decide what to buy and plant. Without knowing this, we can't tell what's likely to happen.
- We have the following ground rules for this focus group:
  - We're using a tape recorder to record the discussion because we can't write as fast as you can speak.
  - In order to keep an accurate record, we ask that you speak one at a time.
  - We want to preserve the confidentiality of our session. We'd like to operate on a first-name-only basis during the session.
  - Afterwards, we will use the tape to transcribe our discussion into written form. In the transcript, you will not be identified by your name but only by speaker one, speaker two, and so on. We will not keep a record of your name, phone number, or any other identifying information, so there will be no evidence that you participated in the group. These precautions will maintain your anonymity.
  - We're taking these precautions because we don't want you to hold back. We're very interested in learning how you decide whether or not to use seed corn with specialized traits.
- For the first question, we'd like to go around the room. After that, just jump in when you have something to say.

Current Farm Operation

Let's go around the room, starting with [*name a participant*] and I'll ask each of you to introduce yourself and tell us a bit about your farm and your corn growing, including:

- Farm size (number of acres)
- How much owned/rented

- Activities
  - Other crops
  - Livestock
- Corn: Which traits? Which companies?
- Your method of weed control and insect control for nonspecialized corn

What do you do with what you produce?

- What percent do you feed to your livestock?
- What do you sell? Where do you sell it?
- How has the market situation changed in the last three years? Where is it headed?

Decision-Making Process

Now, what we want to focus on is how you decide which corn hybrids to plant and how much to plant, but first I want to start with a more general question. -

Thinking of your farm, which corn seed characteristics are important to you? (Big sheets)

Thinking of the "worst" hybrid you planted, what didn't you like about it?

Thinking of the "best" hybrid you planted, what did you like about it?

How often do you change the corn hybrids that you plant?

- *Every year*
- *Every other year*
- *Every five years*
- *Depends on the hybrid*

Thinking of this past year, did you change any of the hybrids? What were your reasons?

We've already been talking about this…We've got the input traits like Bt, Roundup Ready®, Liberty Link®, etc. and we've got the output traits like high oil and high protein. *Actual traits listed in response to earlier questions will be included in this question. This is a set of some possible responses.*

Let's start with input traits. What are your concerns associated with input traits? What are the benefits of input traits?

Thinking about output traits, what are your concerns associated with output traits? What are their benefits?

What is different between output traits and input traits? Are there different risks associated with the two?

Information Sources

Where do you usually get information to help you deal with the problems you've mentioned and, in particular, to help you make planting decisions?

- *Primary sources of information on farm practices*
- *Membership in farm organizations–how active?*
- *Cooperative/marketing organizations*
- *Cooperative Extension service*

Which sources of information are the most important to your decisions?

What makes them important?

- *Accuracy*
- *Comfort–understandable*

Survey

Now let's take about 15 minutes for you to fill out this sample survey. When you're done, we'll talk about your reactions question by question.

Starting with the first question…

Was the question clear? Did the possible answers make sense?

Conclusion

Do you have any final thoughts that you'd like to share with us?

Thank you very much. We hope to report the results of our study to Farm Bureau members next summer. We appreciate your contributions to the project. -

APPENDIX B

2000 SURVEY ON PLANTING DECISIONS

conducted and funded by
the University of California, Davis
in cooperation with the Iowa Farm Bureau

SECTION 1. PRODUCTION PLANNING

1. Which, if any, of the following crops do you produce? **Circle all that apply**.

   Soybeans 1
   Alfalfa 2
   Oats 3
   Corn 4
   Other grains 5
   Specialty crops 6

2. Do you raise any livestock for sale?

   Yes 1
   No .... (skip to question 4)... 2

3. Which of the following best describes animal production on your operation? **Circle all that apply**.

   Hog finishing 1
   Hog farrowing 2
   Cow/calf 3
   Feedlot 4
   Dairy 5
   Sheep 6
   Poultry 7
   Other livestock 8

4. In **1999**, please tell us how many acres you planted in the following types of soybeans? Make an estimate but be as accurate as possible.

   acres Roundup Ready soybeans _______

   acres in STS soybeans _______

   acres in conventional soybeans _______

   acres in specialty soybeans _______

5. In **2000**, please tell us how many acres you planted in the following types of soybeans? Make an estimate but be as accurate as possible.

   acres Roundup Ready soybeans _______

   acres in STS soybeans _______

   acres in conventional soybeans _______

   acres in specialty soybeans _______

6. We are interested in how your use of corn with specialized traits, such as Bt and High Oil corn, has changed since 1997. Please estimate the number of **acres** you planted in each specialized trait for 1997-1999, and please tell us the number of **acres** you plan to plant in each specialized trait for 2000. We know this may be difficult to remember, so just give us your best guess. If you didn't plant a certain trait, just mark zero.

Specialized traits	1997	1998	1999	2000
Bt corn	_______	_______	_______	_______
Roundup Ready corn	_______	_______	_______	_______
Liberty Link corn	_______	_______	_______	_______
Clearfield (IMI) corn	_______	_______	_______	_______
High Oil corn	_______	_______	_______	_______
White corn	_______	_______	_______	_______
Stacked traits	_______	_______	_______	_______
Other specialized corn	_______	_______	_______	_______
Conventional corn	_______	_______	_______	_______

SECTION 2. CORN PRODUCTION PRACTICES

1. Please estimate the percentage of your corn acreage you reduce till, no till, or plow.

   percent reduce till (no plow) _______%

   percent no till _______%

   percent plow _______%

2. Which of the following practices do you use to control **weeds** on your corn fields? **Circle all that apply**.

   Mechanical cultivation 1
   Rotary hoeing 2
   Crop rotation 3
   Herbicides 4
   Planted seed with good weed resistance due to fast seedling development 5
   Planted herbicide resistant seed 6
   Delay planting date 7

3. How concerned are you about weed pressure on your farm? **Circle only one**.

   Major concern 1
   Minor concern 2
   Not a concern 3

4. Which, if any, of the following practices do you use to estimate **European Corn Borer** populations on your corn fields? **Circle all that apply**.

   I hire someone to scout my fields 1
   I scout my own fields 2
   I don't measure corn borer pressure 3

5. How concerned are you about damage by European Corn borer on your farm? **Circle only one**.

   Major concern 1
   Minor concern 2
   Not a concern 3

6. For the coming crop year, what is the **smallest** number of bushels per acre, if any, that you expect to lose to damage by the European Corn Borer?

   _______ bu/acre

7. For the coming crop year, what is the **largest** number of bushels per acre, if any, that you expect to lose to damage by the European Corn Borer?

   _______ bu/acre

8. For the coming crop year, what is the **most likely** number of bushels per acre, if any, that you expect to lose to damage by the European Corn Borer?

   _______ bu/acre

SECTION 3. CORN MARKETING OPPORTUNITIES

1. For **1999**, give us your best estimate of what percent of your corn you:

   feed _______%

   sell at harvest _______%

   store on farm _______%

   store at elevator _______%

2. What was your total corn harvest in 1999? _______ bu

3. What is the total volume of your on-farm corn storage capacity?

   _______ bu

4. How many separate grain bins do you have? _______

5. How many dryers do you have?

   number of **batch or bin** dryers _______

   number of **continuous flow** dryers _______

6. Suppose you were offered a premium to identity preserve (segregate) non-GMO conventional corn at 95% purity for January delivery to a local grain elevator. Would you identity preserve your non-GMO corn at 95% purity for **20** cents/bushel?

   Yes .... (go to question 7)... 1
   No .... (skip to question 8)... 2

7. Would you identity preserve your non-GMO corn at 95% purity for **10** cents/bushel?

   Yes .... (skip to section 4)... 1
   No .... (skip to section 4)... 2

8. Would you identity preserve your non-GMO corn at 95% purity for **30** cents/bushel?

   Yes 1
   No 2

SECTION 4. SPECIALTY CORN

1. Do you grow any White corn, High Oil corn, or other specialized feed corn?

   Yes 1
   No .... (skip to section 5)... 2

2. In 1999, did you produce any **White corn** under contract? **Circle only one**.

   Yes 1
   No .... (skip to question 5)... 2

3. How much White corn did you contract? _______ bu or acres

4. What was the premium per bushel for the White corn? _______

5. In 1999, did you produce any **High Oil** corn under contract? **Circle only one**.

   Yes 1
   No .... (skip to question 9)... 2

6. How much High Oil corn did you contract? _______ bu or acres

7. What was the oil content of your High Oil corn? _______

8. What was the premium per bushel, based on your oil content? _______

9. In 1999, did you produce any **other specialized feed** corn under contract? **Circle only one**.

   Yes 1
   No .... (skip to section 5)... 2

10. How much other specialized feed corn did you contract? _______ bu or acres

11. What was the premium per bushel for your other specialized feed corn? _______

SECTION 5. WHERE DO YOU GET INFORMATION?

1. Overall, how important is this information source to your planting decision?

	I don't use	not at all important	somewhat important	very important
Seed dealer	1	2	3	4
Chemical supplier	1	2	3	4
Pest control adviser	1	2	3	4
Extension agent	1	2	3	4
Agricultural publications	1	2	3	4
Farm shows and fairs	1	2	3	4
Other farmers	1	2	3	4
Internet	1	2	3	4
Iowa State test yields	1	2	3	4

2. Do you think this information source provides reliable corn seed information?

	not at all reliable	somewhat reliable	very reliable
Seed dealer	1	2	3
Chemical supplier	1	2	3
Pest control adviser	1	2	3
Extension agent	1	2	3
Agricultural publications	1	2	3
Farm shows and fairs	1	2	3
Other farmers	1	2	3
Internet	1	2	3
Iowa State test yields	1	2	3

3. Did you plant a test plot in1999?

   Yes 1
   No 2

SECTION 6. ISSUES AND CONCERNS

Now we'd like to ask you some questions about your issues and concerns. For the following statements, please tell us if you strongly agree, somewhat agree, agree, somewhat disagree, or strongly disagree. **Circle only one per line**.

	strongly disagree	somewhat disagree	neither agree nor disagree	somewhat agree	strongly agree
Maintaining a system of family-operated farms is essential to the future of rural Iowa.	1	2	3	4	5
Large-scale corporate farming is a threat to the future of rural Iowa.	1	2	3	4	5
If the economic situation for farmers continues like it is now, in a few years the family farm will be replaced by large farms run by hired labor.	1	2	3	4	5
The replacement of family farms by large-scale farms using hired labor would have undesirable economic and social consequences for the nation.	1	2	3	4	5
I would rather take more of a chance on making a big profit than be content with a smaller but less risky profit.	1	2	3	4	5
I regard myself as the kind of person who is willing to take more risks than the average farmer.	1	2	3	4	5
Farmers who are willing to take chances usually do better financially.	1	2	3	4	5
Agricultural biotechnology will be beneficial for consumers.	1	2	3	4	5
Consumers will benefit more than farmers from biotechnology research.	1	2	3	4	5
Consumers will not accept some food products from biotechnology.	1	2	3	4	5
Biotechnology will help solve the problem of farm surpluses by finding new uses for crops and livestock.	1	2	3	4	5
Biotechnology will increase the standard of living for most farm families.	1	2	3	4	5
Biotechnology will enable farmers to become less dependent upon agricultural chemicals.	1	2	3	4	5
Biotechnology will hurt American farmers by increasing farm surpluses.	1	2	3	4	5
Biotechnology will be beneficial for most Iowa agricultural producers.	1	2	3	4	5

SECTION 7. WHAT ABOUT YOURSELF?

1. Where do you farm?

   county ________________

   zip code ______

2. What was your age at your last birthday?

   years _______

3. How long have you been actively farming?

   years _______

4. What is the highest level of formal education you have completed? **Circle only one**.

   Grade school 1
   Some high school 2
   High school diploma 3
   Some college work 4
   Some vocational technical work 5
   2-year community college degree 6
   4-year college degree 7
   Some post graduate work 8
   Post graduate degree 9

5. Do you consider farming your principal occupation?

   Yes .... (skip to question 7)... 1
   No 2

6. What is your principal occupation?

   ____

7. How many planted acres did you **own** in 1999?

   planted acres _______

8. How many planted acres did you **rent** in 1999?

   planted acres _______

9. What is your farm's average Corn Suitability Rating?

   CSR _______

10. How many family members work on the farm?

    ____

11. How many people does the farm employ?

    ____

This question will only be used as a measure of farm size.

12. From the following general categories below, please select the range which best describes your total gross farm income in 1999. (Total gross farm income is the value of products sold, farm land rented income, government programs, etc.) **Circle only one**.

Less than $10000 1
$10,000-19,999 2
$20,000-$24,999 3
$25,000-$39,999 4
$40,000-$49,999 5
$50,000-$99,999 6
$100,000-$249,999 7
$250,000-$499,999 8
$500,000 or more 9

APPENDIX C
REPRESENTATIVENESS OF SURVEY RESPONDENTS

In this appendix, we compare survey respondents to the representative Iowa producer. The 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 producers. Less subjectively, the sample is deliberately biased toward producers with larger farms relative to the overall population. Most of the differences can be explained by our minimum-size requirement. According to Sands and Holden, in 1998 the average size of an Iowa farm was 340 acres. Among survey respondents, the average farm was 562 acres for the 2000 crop year. Survey respondents had larger gross farm incomes than Iowa farmers as a whole, as reported in Table C.1. For 1999, 62 percent of respondents had a gross farm income of $100,000 or more compared to 35 percent of Iowa farmers in the 1997 Census of Agriculture. A larger share of respondents (84 percent) than in the overall population (62 percent) farm full time, which is consistent with full-time farmers operating larger farms than part-time farmers.

In Table C.2, we compare respondents' planting decisions to results of surveys by the National Agricultural Statistics Service (NASS) on planting intentions (USDA, 2000b, 1999b), and to NASS data on actual planted acreage (USDA, 2000a). Respondents planted a larger share of their acreage to GM crops than farmers in the nation as a whole. Respondents plan to increase their share of GM soybeans while, based on the March Prospective Plantings surveys (USDA, 2000b), the major soybean producing states will decrease the share of soybean acreage planted to GM soybeans.[6] However, the June acreage survey (USDA 2000a) shows that Iowa planted

Table C.1. **Total Gross Farm Income**

Income Category	Respondents 1999	1997 Census of Agriculture
Less than $10,000	2.2%	26.0%
$10,000–$49,999	20.3%	24.2%
$50,000–$99,999	15.4%	15.1%
$100,000–$249,999	35.0%	21.1%
$250,000 or More	27.1%	13.6%

Table C.2. **Share in GM Crops: Survey Respondents and NASS Respondents -**

	Share of GM Soybeans[a] (Percent)			Share of GM Corn (Percent)		
	NASS Prospective Plantings Survey[c]	NASS Acreage Survey[d]	Survey[b]	NASS Prospective Plantings Survey	NASS Acreage Survey	Survey
1999	57	NA	61	33	NA	37
2000	52	59	66	25	30	35

[a] The 1999 NASS March prospective plantings report included herbicide-tolerant soybeans obtained by conventional breeding techniques.
[b] Survey of Iowa farmers, February–March 2000. The data reported for 1999 are acres planted, and the data for 2000 are planting intentions.
[c] The data apply to regions that produce the majority of corn and soybeans. For corn, the region includes Illinois, Indiana, Iowa, Minnesota, Nebraska, Ohio, and Wisconsin. For soybeans, the region includes Arkansas, Illinois, Indiana, Iowa, Minnesota, Missouri, Nebraska, and Ohio. The data for 1999 are based on percent of harvested acres.
[d] The data reported are specific to Iowa.

[6] The 1999 NASS survey included conventionally bred herbicide-tolerant (STS®) soybeans in the GM category. If the share of STS® soybeans was larger than 5 percent, then the share of GM soybeans may be increasing in the nation. However, this is unlikely because STS® soybeans only accounted for 2 percent of the soybean acreage in the sample in 1999.

a substantially larger share of their soybean acreage to GM soybeans than indicated by the March prospective plantings survey of the major soybean-producing states. Without Iowa-specific data on the acres planted to GM soybeans in 1999, we cannot precisely compare the survey results with NASS data.

Both the NASS prospective plantings survey of major corn-producing states and the survey found that farmers plan to decrease their acreage in GM corn. Again, Iowa-specific data from the NASS June acreage survey demonstrates that Iowa farmers allocate more of their acreage to GM corn than do producers in the major corn-producing states. Overall, the comparison suggests that the sample is reasonably representative of the producers growing the vast majority of Iowa corn.

APPENDIX D
PROOFS

Proof of Proposition 1

We assume complete land utilization, $A_c + A_{gm} = \bar{A}$. For the case $A_c > 0, A_{gm} > 0$, the first-order condition is

$\frac{\partial U(W)}{\partial A_{gm}} = E\left[U'(W)\frac{\partial W}{\partial A_{gm}}\right] = 0$, where $\frac{\partial W}{\partial A_{gm}} = (P-d)Y_{gm} - C_{gm} - Z_{gm} - (PY_c - C_c - Z_c)$.

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,

$\bar{W} = \left[P_A\bar{A} + (P\bar{Y}_c - C_c - \bar{Z}_c)(\bar{A} - A_{gm}) + ((P-\bar{d})\bar{Y}_{gm} - C_{gm} - \bar{Z}_{gm})A_{gm}\right]$.

After substituting for $U'(W)$ and $\bar{W}$, dividing by $U'(\bar{W})$ and taking expectations, we obtain

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

where

$ER_{gm} = \left((P-\bar{d})\bar{Y}_{gm} - C_{gm} - \bar{Z}_{gm}\right), ER_c = (P\bar{Y}_c - C_c - \bar{Z}_c),\ var(C) = (P^2\sigma^2_{Y_c} + \sigma^2_{Z_c}),$

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

Solving for A_{gm} and using the assumption of complete land utilization, $A_{gm} = \frac{ER_{gm} - ER_c + \bar{\phi}\bar{A}var(c)}{\bar{\phi}(var(c)+var(gm))}$, and $A_c = \bar{A} - A_{gm} = \frac{ER_c - ER_{gm} + \bar{\phi}\bar{A}var(gm)}{\bar{\phi}(var(c)+var(gm))}$.

We examine the second-order condition to ensure that the solution is a maximum. The wealth elasticity of risk aversion is defined as $\eta = -\bar{\phi}'\frac{\bar{W}}{\bar{\phi}}$. We assume that relative risk aversion is nondecreasing and absolute risk aversion is nonincreasing, so $0 < \eta < 1$. Hence the second-order condition is

$\frac{1}{U'(\bar{W})}\left(\frac{\partial^2 U(W)}{\partial A^2_{gm}}\right) = -\bar{\phi}(var(c) + var(gm))\left[1 - \eta\frac{ER_{gm} - ER_c}{\bar{\phi}(var(c)+var(gm))}\frac{ER_{gm} - ER_c}{\bar{W}}\right] < 0.$

The objective function is concave in A_{gm} provided $1 - \eta\frac{ER_{gm} - ER_c}{\bar{\phi}(var(c)+var(gm))}\frac{ER_{gm} - ER_c}{\bar{W}} > 0$.

From our restriction on η, we know

$1 - \eta\frac{ER_{gm} - ER_c}{\bar{\phi}(var(c)+var(gm))}\frac{ER_{gm} - ER_c}{\bar{W}} > 1 - \frac{1}{\bar{W}\bar{\phi}}\frac{(ER_{gm} - ER_c)^2}{var(c) + var(gm)}$.

From the definition of A_{gm}, we know $\frac{ER_{gm} - ER_c}{\bar{\phi}(var(c)+var(gm))} < A_{gm}$.

Accordingly,

$1 - \frac{1}{\bar{W}\bar{\phi}}\frac{(ER_{gm} - ER_c)^2}{var(c) + var(gm)} > 1 - \frac{(ER_{gm} - ER_c)A_{gm}}{\bar{W}}$.

Examining the expression on the right, the difference in expected revenue between the two alternatives multiplied by A_{gm} is clearly less than total wealth, $\bar{W}$. Regardless of the sign of $ER_{gm} - ER_c$, the expression as a whole is positive. By transitivity,

$1 - \eta\frac{ER_{gm} - ER_c}{\bar{\phi}(var(c)+var(gm))}\frac{ER_{gm} - ER_c}{\bar{W}} > 0.$

Proof of Proposition 2

Assuming full land utilization, the Kuhn-Tucker conditions for the producer's maximization decision are
$\frac{\partial \mathcal{L}}{\partial A_{gm}} = E\left[U'(W)\frac{\partial W}{\partial A_{gm}}\right] - \mu_1 + \mu_2 = 0;$
$A_{gm} \geq 0,$
$A_{gm} \leq \bar{A};$
$\mu_1 \geq 0,$
$\mu_2 \geq 0,$
$\mu_1 A_{gm} = 0,$
$\mu_2(A - A_{gm}) = 0.$
There are four possible cases.
Case 1: $\mu_1 > 0, \mu_2 > 0 \Rightarrow A_{gm} = 0, A_{gm} = \bar{A}$. Contradiction. Case 1 is not a solution.
Case 2: $\mu_1 = 0, \mu_2 = 0 \Rightarrow 0 < A_{gm} < \bar{A}$. This is the interior solution examined in Proposition 1.
Case 3: $\mu_1 > 0, \mu_2 = 0 \Rightarrow A_{gm} > 0, A_{gm} = \bar{A}$. The producer allocates all of his acreage to the GM crop. To demonstrate necessity, we establish that, if the producer does not plant all of his acreage to the GM crop, then the inequality in condition A does not hold. In this case, $\bar{A} > A_{gm}$ and the first-order condition implies
$ER_{gm} = ER_c + \bar{\phi}\left(var(gm)\bar{A} + (var(gm) + var(c))(A_{gm} - \bar{A})\right).$
The final term, $\bar{\phi}(var(gm) + var(c))(A_{gm} - \bar{A})$, is negative, which implies that
$ER_{gm} < ER_c + \bar{\phi}\bar{A}var(gm).$
Condition A is necessary for the producer to plant all of his acreage to the GM crop.
Case 4: $\mu_1 = 0, \mu_2 > 0 \Rightarrow A_{gm} = 0, A_{gm} < \bar{A}$. The producer allocates all of his acreage to the conventional crop. To demonstrate necessity, we establish that, if the producer does not plant all of his acreage to the conventional crop, then the inequality in Condition B does not hold. In this case, $\bar{A} > A_c$ and the first-order condition implies that
$ER_c = ER_{gm} + \bar{\phi}\left(var(c)\bar{A} - (var(gm) + var(c))A_{gm}\right).$
The final term, $-\bar{\phi}(var(gm) + var(c))A_{gm}$, is negative, which implies that
$ER_c < ER_{gm} + \bar{\phi}\bar{A}var(c).$
Condition B is necessary for the producer to plant all of his acreage to the conventional crop.

Proof of Proposition 3

Consider three distributions, each fully defined by its first two moments: $H \sim (\mu, \sigma^2)$; $F \sim (\mu_F, \sigma^2)$; $G \sim (\mu, \sigma_G^2)$ where $\mu_F > \mu, \sigma_G^2 > \sigma^2$. Then, $H \succ G$ for all risk-averse individuals and $F \succ H$ for all risk-averse and risk-neutral individuals. Therefore, by transitivity, $F \succ G$.

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