# Factors Affecting the Adoption of Genetically Modified Crops by Young and Beginning U.S. Farmers and Ranchers

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## Abstract

The comprehensive set of programs in the 2008 Farm Bill designed to support Young and Beginning Farmers and Ranchers (YBFR), combined with a substantial amount of resources allocated to each of these programs, can be viewed as an investment in ensuring the future sustainability of the U.S. agriculture system. Understanding the factors that influence YBFR to adopt technology will become increasingly important if YBFR are to succeed. Of particular interest is why YBFR adopt Bt corn, Bt cotton, and HT soybeans. Results conform to a majority of our a priori expectations; YBFRs are more likely to adopt GM crops if they are not a full owner of the farm operation, as sales of the farm operation grow, if the crop is important to their region, and as they become more risk averse.

## Introduction

The passage of the 2008 Farm Bill provides many provisions and policies designed to assist Young and Beginning Farmers and Ranchers (YBFR). A beginning farmer or rancher, as defined by the Farm Service Agency (FSA), is an individual or entity who has not operated a farm or ranch for more than 10 years, substantially participates in the operation, and if the applicant is an entity, all members must be related by blood or marriage, and all stockholders in a corporation must be eligible beginning farmers. Some of the YBFR provisions include competitive grants that are to be used in education, extension, and outreach initiatives to help YBFR to get started, and improvements to the beginning farmer and rancher loan program. In addition, five percent of the funding in each conservation program is set aside for beginning and socially disadvantaged farmers (equating to tens of millions of dollars each year) (National Catholic Rural Life Conference, 2008; National Association of Wheat Growers, 2008; Baker and Klien 2008).[1]

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The comprehensive set of programs in the 2008 Farm Bill designed to support YBFR, combined with substantial amount of resources allocated to each of these programs, can be viewed as an investment in ensuring the future sustainability of U.S. agriculture. Given that many of these provisions are support programs that provide educational and technical assistance on farm management practices, it is essential that economic research investigate the wide variety of strategies that might be implemented by YBFR as a means for improving their economic viability. One farm management strategy that is becoming increasingly important is the adoption of genetically modified (GM) crops as part of a farm's crop rotation. GM crops are those crops that help fight pest/insect or weed infestations. Their adoption by U.S. farmers occurs because of the cropping and production efficiency gains associated with their adoption. Adoption of these new plant varieties in production agriculture is occurring across the globe. For example, the use of Bacillus thuringiensis (Bt) corn grew from about eight percent of U.S. corn acreage in 1997 to 49 percent in 2007, while Herbicide Tolerant (HT) soybeans went from 17 percent of U.S. soybean acreage in 1997 to 68 percent in 2001 and 92 percent in 2007 (Fernandez-Cornejo, 2007). Moreover, little research exists that investigates factors affecting adoption of genetically modified row crops by YBFR. Understanding these factors will be critically important to the success of YBFR in the U.S.

The primary objective of this paper is to identify factors that influence the adoption of GM crops by YBFR in the U.S. This study will explore the impact of factors such as farm, operator demographics, location, and financial characteristics on the adoption of GM crops by YBFR in the U.S. YBFR have different needs than established farmers, and thus it is likely the factors that influence adoption of GM crops might also be different. First, the scales of their operations are often insufficient to realize profits; they lack experience in farm operation management; and they often face problems associated with high land values and production costs when compared to their non-YBFR peers (Mishra and El-Osta, 2007). YBFR and their spouses are typically more educated than their non-YBFR peers; this makes them more likely to seek higher paying off-farm employment (Mishra et al., 2002). As a result, they are reluctant to try traditional and time-consuming farming processes using older technologies and more likely to adopt new and innovative technologies which reduce the time spent working on the farm. The results of this analysis will provide a better understanding of why some YBFR choose to incorporate GM crops in their crop rotation.

## Literature Review

Technology adoption by a farm operator typically occurs for one of three reasons: 1) the potential increase in the farm operation's output; 2) more efficient use of inputs; and/or 3) a reduction in the likelihood of the farm operation failing if the new technology is used correctly (Robison and Barry, 1987). The adoption of GM crops by U.S. farmers provides economic benefits through higher yields, lower pesticide costs, and savings in management time, although the magnitude of these impacts vary with GM crop, technology, pest infestation levels, and other factors (Fernandez-Cornejo, 2007).

Some of the major GM crops grown in the U.S. are Bt corn, HT soybean, and Bt cotton. Bt corn is genetically modified corn that produces an insecticidal toxin (Bt toxin) that provides insecticidal control for Lepidoptera larvae, caterpillars (European corn borer) (Hammond, Michel, Eisley, 2009). Bt cotton helps control tobacco budworm, bollworm, and pink bollworm (Fernandez-Cornejo, 2007). HT soybeans, commonly known as Roundup-Ready® (RR) soybeans, are soybeans that have been modified to be highly resistant to the broad-spectrum herbicide, glyphosate, allowing farmers to control weeds more effectively but with smaller amounts of less toxic and less persistent pesticides (Goklany, 2007).

Over six decades ago, Griliches (1957) studied hybrid corn as an indicator of technological change. Nearly, five decades later, Solow (1994) and Griliches (1995) pointed out that technology has been a critical component of productivity growth and perhaps more importantly an economic growth engine. Technological change can affect profits, real wages, employment, and trade (Huffman and Evenson, 2006). Paz, et al. (2009) lists the following advantages of using HT soybeans: 1) their use decreases herbicide costs; 2) increases glyphosate applications compared to other types of herbicide; and 3) facilitates farm families to reassign their time to other income-earning activities. Holtzapffel, et al. (2008) in their study of Australian farmers found that GM cotton was more profitable and easier to grow when compared to conventional cotton. In addition, GM cotton decreased occupational health and safety incidents because of the reduction of chemical use and manual weed control in cotton fields; improved community perceptions of the cotton industry because of the altered use of chemicals; reduced spending on insecticides, herbicides and their application. In their analysis of a 2001 survey of farmers, Fernandez-Cornejo and Li (2005) found that on average the adoption of Bt corn increased yields by nine percent and decreased insecticide use per planted acre by eight percent relative to non-Bt corn.

Research that has examined profitability of adoption compared to non-adoption however, has been inconclusive. Using the 1997 national survey of soybean producers, McBride and Brooks (2000) compared costs of an herbicide-tolerant soybean variety and conventional soybean varieties and found no significant differences. Fernandez-Cornejo, et al.(2000), using the same data but controlling for cropping practices, agronomic conditions, and producer attributes, also found no statistical differences in rates of returns of adopters and non-adopters of a herbicide-tolerant soybean variety. Studying the impacts of adopting herbicide-tolerant corn on net returns, Fernandez-Cornejo and Klotz-Ingram (1998) found no significant differences. Work by Marra, et al. (2002); however, shows that the adoption of transgenic cotton in the U.S. Cotton Belt, Bt corn in the U.S. Corn Belt and, RR soybean varieties will lead to operations that are more profitable than farm operations that are non-adopters. While these studies focused on the costs and benefits of adopting genetically engineered crops (soybean and corn), none have investigated the issue of adoption as it relates to YBFR in the U.S. Furthermore, it is likely that YBFR have different sets of attributes and skills, which may affect adoption rates, including more education, having a job off the farm, and greater receptiveness to adopting new technology such as GM crops (Batte and Johnson 1993). YBFR may adopt GM crops with the expectation that GM crops will reduce total time spent on farming activities related to the crop and potentially increase their ability to work off-farm.

Feder, et al. (1985) present a comprehensive literature review on adoption and diffusion of technology in agriculture. Many researchers have examined the influence of farmers' attributes on adoption of agricultural innovations (e.g., Rahm and Huffman, 1984; Caswell and Zilberman, 1985). In the past, studies have focused on technological innovations that increased agricultural productivity. In the 1970s and 1980s, several studies focused their attention on the adoption of environmentally preferable technologies (Fernandez-Cornejo, et al., 1998). With the start of the 21st century, many U.S. farmers are adopting biotechnological innovations such as genetically modified crops , also known as bioengineered crops that have implications for productivity, the environment, consumer preferences and acceptability, and agricultural trade.[2]

## Empirical Framework

Since the dependent variable in our model is the share of GM crop acres (corn, cotton, and soybean) in total operated acres, a Tobit model (Tobin, 1958) was used to model factors that influence the adoption of genetically engineered crops. This method estimates the likelihood and extent (i.e., intensity) of adoption. The Tobit approach has been applied in previous studies of agricultural technology adoption (Norris and Batie, 1987; Gould, et al., 1989; Adesina and Zinnah, 1993). More specifically, the two-limit Tobit is appropriate since the dependent variable is the proportion of the acreage with the technology; thus, the dependent variable must be between 0 and 1 (Rossett and Nelson, 1975; Maddala, 1992; Long 1997).

Fernandez-Cornejo and McBride (2002) studied the extent of and factors affecting the adoption of bioengineered crops (Bt corn and HR soybeans) among U.S. farmers. The authors concluded that adoption of genetically engineered crops was positively correlated with operator's education, experience and use of contracting. In the sociology literature, Rogers (1995) lists five technology attributes that affect the rate of adoption. These include relative advantage (such as profitability, initial cost status, timesavings), compatibility (i.e., similarity with previously adopted innovations), complexity (i.e., degree of difficulty in understanding and use), trailability (i.e., ease of experimentation), and observability (i.e., degree to which results of innovation are visible). Using this characterization, adoption of GM crops has several unique attributes that would be expected to increase adoption rate by YBFR.

Adoption of an innovation will tend to take place earlier on larger farms rather than on smaller farms (Just, et al., 1980). More experienced farm operators, i.e., those with better management capabilities would be more likely to adopt technology. We follow Goodwin and Mishra, (2004) and use cropping efficiency (*CROP_EFF*), ratio of gross cash farm income to total variable costs as a proxy for farming management capabilities. Greater human capital of operators of large farms may explain why large farms have higher propensities to adopt new technology. Batte and Johnson (1993) indicate young farmers tend to have more education, which makes them more willing to innovate. Consequently, we expect the age of the operator (*AGE*) to influence negatively the adoption of GM acreage in the farm operation. While education of the operator (*EDUC*), size of the farm (*LARGE*), and productivity of the farm (*MEANPI*) should positively influence adoption.

Farm ownership is widely believed to affect technology adoption. Results however, have been widely debated (Feder, et al., 1985). Bultena and Hoiberg (1983) find no support for the hypothesis that land tenure had a significant impact on adoption of conservation tillage. Results on land tenure and technology adoption could hinge on the nature of innovation. If the innovation requires an investment in land, then one might expect that tenants would not adopt the technology because they perceive that the benefits of adoption would not necessarily accrue to them. Nevertheless, adoption of GM crops, which are not tied to investment in land, may not be affected by farm ownership. Consequently, to account for land ownership characteristics we include whether the farmer is a tenant (*TENANT*) and/or a part- owner (*POWNER*) as explanatory variables in the model.

Mishra, et al. (2002) conclude that farm households supply labor to both farm and nonfarm activities. Consequently, if a YBFR is allocating time to a nonfarm job the farm operator will seek to eliminate management intensive technologies as they occupy too much of the time allocated for farm management (McNamara, et al., 1991). If the technology is farm-labor saving however, adoption of such technologies might be encouraged. Operator's off-farm work experience (*OPOWKEXP*) is included in the model to assess the impact of off-farm work on adoption of GM crops by YBFR in the U.S.

Finally, adoption of technology may be influenced by the risk aversion of the farm operator. Alexander, et al. (2000) examined the role of risk aversion of producers in the adoption of GM crops. The authors found that risk aversion is positively and significantly related the decision to plant GM corn. Following Goodwin and Rejesus (2008), we use share of crop/livestock insurance premiums in total variable cost as a measure of risk aversion (R_AVERSION). Summary statistics of the independent variables used in the analysis are presented in Table 1.

## Data

Data for this analysis are from the 2004-2006 Agricultural Resource Management Survey (ARMS). The Economic Research Service and the National Agricultural Statistics Service conduct the ARMS annually. The survey collects data to measure the financial condition (farm income, expenses, assets, and debts) and operating characteristics of farm businesses, the cost of producing agricultural commodities, and the well-being of farm operator households.

The target population of the survey is operators associated with farm businesses representing agricultural production in the 48 contiguous states. A farm is defined as an establishment that sold or normally would have sold at least $1,000 of agricultural products during the year. Farms can be organized as proprietorships, partnerships, family corporations, nonfamily corporations, or cooperatives. Data are collected from one operator per farm, the senior farm operator. A senior farm operator is the operator who makes most of the day-to-day management decisions. For the purpose of this study, operator households organized as nonfamily corporations or cooperatives and farms run by hired managers were excluded.

The 2004 to 2006 ARMS contains data on 19,638 farms that are classified as YBFR. Using the sampling weights, the sample represents a population of 412,321 farms operated by YBFR at the national level (Table 2). The survey design of ARMS allows each sampled farm to represent a number of farms that are similar, referred to as a survey expansion factor. The expansion factor, in turn, is defined as the inverse of the probability of the surveyed farm being selected. A weighted means (expanded by the expansion factor, which is the weight) procedure is used to extrapolate representative sample to a population. This is based on the procedure that is specific to the ARMS data (Dubman, 2000).

Since, the ARMS data has a complex survey design and is cross-sectional; it raises the possibility that the error terms in both logistic models are heteroskedastic. Accordingly, all standard errors were adjusted for heteroskedasticity using the Huber-White sandwich robust variance estimator based on algorithms contained in STATA (Huber, 1967; White, 1980). Further, this type of adjustment for standard errors was used in the regression models in lieu of the Jackknife variance estimation method when a subset of the main dataset is analyzed (Mishra and El-Osta, 2007). For this study, the subset of data taken from the ARMS dataset is for those farms that are only operated by YBFR.

The 2004 to 2006 ARMS collected information on both farm business and farm household data. For example, it collected detailed information on off-farm hours worked by spouses and farm operators, the amount of income received from off-farm work, net cash income from operating another farm/ranch, net cash income from operating another business, and net income from share renting. The heavy emphasis in off-farm employment of operators and spouses suggests (Table 2) that farm household have an alternate goal to generating maximum household income for the farm business operation.[3] Furthermore, income received from other sources, such as disability, Social Security, and unemployment payments, and gross income from interest and dividends, was also counted.

Table 2, also shows that, on average, YBFRs operate small farms (about 168 acres), the majority of which are owned, however; YBFRs are twice (11%) as likely to be tenants[4] as compared to all other farm operators (5 percent), and approximately twice as likely to specialize in general livestock farming. Focusing on the regional location and farming type of YBFRs, Table 2 also shows that YBFR farm are more likely to be located in the Southern Plains, Corn Belt, and Appalachia regions of the U.S. and are likely to be engaged in beef cattle and general livestock operations. Among other things, viable farm business ventures are a by-product of business planning (Johnson and Morehart, 2006). A completed business plan expands upon opportunities and determines whether a new business venture is feasible or not. Developing a business plan is a process that helps farmers focus on factors necessary for future business success (Johnson and Morehart, 2006). An initial benefit of engaging in the business planning process is assisting[5] farmers in defining realistic goals that will make their proposed venture viable into the future. Organizing thoughts and ideas into a formal plan sets farms on a path of success and provides a means to measure actual outcomes against business goals (Johnson and Morehart, 2006). In 2006, farm operators were queried to determine whether they had a written business plan. Results show that about 14 percent of YBFR had written business plans.

## Results

Tobit parameter estimates for the adoption model for share of GM crops in total operated acres are presented in Table 3.[6] The log-likelihood ratio $\chi 2$ statistics [-2 log L], which tests the joint significance for the independent variables included in the model are significant at the one percent level of significance. Table 3 shows that the pseudo-R2 is 0.24 for the cotton model and 0.48 for the soybean and corn models, indicating good fits.[7]

Table 3 reports the parameter estimates and predicted marginal effects[8] of the factors that influence the adoption of GM corn, cotton, and soybeans by YBFR. First, results show that off-farm work experience (*OPOWKEXP*) decreased acreage in all GM crops. An additional year of off-farm work experience decreased the share of Bt corn acres by -0.05 percent, Bt cotton acres by -0.09 percent, and HT soybean acres by 0.04 percent. *OPOWKEXP* is negatively statistically significant at the one percent level for all three crops. This finding runs counter to our *a priori* expectation that YBFR with off farm work experience would want to adopt GM crops to decrease the number of hours they spend working on the farm in order to have more time available for other activities. While these results may seem counter-intuitive, there is a plausible reason for this result. Robison and Barry (1987) suggest that when individuals lack the necessary skill set for using a new technology, they will not adopt that technology. Consequently, off-farm work experience (*OPOWKEXP*) decreased time allocated to the farm operation, making the farm operators less confident in their abilities for the successful application of GM crops.

Results confirm our *a priori* expectation that educated (*EDUC*) YBFR operators are more likely to adopt GM crops for cotton; however, the magnitude of this factor is very small. For example, an additional year of schooling increased the acreage of Bt cotton approximately 0.2 percent. For HT soybean adoption, *EDUC* is negatively and statistically significant at the one percent level. Again, these results may seem counter-intuitive, there are some plausible reasons for this result. First, if non-adoption can lead to disastrous outcomes, then the farm will almost certainly adopt the new technology and adoption will be widespread (Robison and Barry, 1987). If the field suffers a pest infestation that could have been controlled by the Bt cotton variety, non-adoption will result in major yield loss. For RR soybeans, the additional year of education makes the farmer more aware that they do not have requisite skill set at preventing herbicide burn, i.e. if other crops in the operation that are not RR somehow were exposed to the Roundup chemical, results could be financially devastating.

Results in Table 3 show that large farm operators (farms with sales of more than $500,000) are more likely to adopt all three GM crops compared to their counterparts (significant at the 1% level for all three GM crops). The magnitude of increase in GM for corn, cotton, and soybean acres is three, five, and two percent, respectively. This result is consistent with Robison and Barry (1987), who indicate that larger firms are more likely to be adopters of new technology because of their expanding resource base. This result is consistent with Rogers' (1995) observation that adoption is more responsive to farm size.

Our findings also indicate that farms specializing in cash grains are more likely to adopt GM crops such as corn and soybean and less likely to adopt GM cotton than other farm types. Cropping efficiency, (*CROP_EFF*), has a negative and significant impact on GM crop adoption by YBFR for both corn and cotton. Perhaps, this is an indication of a farm operator's unwillingness to introduce new technology, given that they are already successful with what they are doing. Consistent with our *a priori* expectation, that as YBFR become more risk averse (*R_AVERSION*) they are more likely to adopt GM crops;[9] results show that the share of Bt corn, Bt cotton, and HT soybeans increase by nine percent, fifteen percent, and seven percent respectively for each percent increase in the share of insurance premiums as part of total variable costs. This is consistent with the notion that GM crops may reduce production risks. Furthermore, *R_AVERSION* is statistically significant at the one percent level in the adoption model for all three GM crops.

Results show that farm ownership plays an important role in adoption of GM crops by YBFR. Results indicate that, compared to full owners, part owners (*POWNER*) and tenants (*TENANT*) are more likely to adopt GM crops. Specifically, being a tenant increases the share of GM corn by three percent, cotton by nine percent, and soybeans by five percent. A part owner increases the share of GM corn, cotton, and soybean by three, six, and four percent, respectively. This occurs because YBFR are likely to be credit constrained. By entering into a farm business arrangement where they do not have full ownership of the farmland allows the YBFR to allocate the funds that would otherwise be used to service farmland debt to purchase GM crops.

Regional dummies were included in the regression to assess the regional impacts of YBFR adopting GM crops. The coefficients for the Heartland region (*HEART*), Northern Crescent (*NORTHC*), Northern Great Plains (*NORTHGP*), Prairie Gateway Region (*PGATE*) Eastern Uplands (*EUPLAND*), and Southern Seaboard (*SSBOARD*) are positive and statistically significant at least at the five percent level for Bt corn adoption. Farms located in the above regions are more likely to adopt Bt corn as part of their corn acreage compared to farms in the benchmark region (Mississippi Portal, see Figure 1), while farms in the Fruitful Rim (*FRIM*) and Basin and Range (*BASINR*) regions are less likely to adopt Bt corn. The farms in those regions that adopt Bt corn more extensively tend to be larger and grow more cash grains. Marginal effects for corn indicate that the probability of adoption of Bt corn is highest in the Heartland region, followed by the Northern Crescent region, and then the Prairie Gateway Region.

Results indicate that, relative to YBFR in the Mississippi Portal region, adoption of GM soybeans was more likely only among YBFR producers in the Heartland region (*HEART*). Thus, concerning the adoption of HT soybeans, results indicate that farm households located in five of eight regions are less likely to adopt HT soybeans compared to the Mississippi Portal region (benchmark region). The magnitude of adoption of HT soybeans ranges from 1.8 percent in the Heartland region to about -3.7 percent for both the Northern Great Plains and the Prairie Gateway regions.

Finally, the coefficients for the Heartland region (*HEART*) and Eastern Uplands (*EUPLAND*) are negative and statistically significant at least at the five percent level for Bt corn adoption compared to the Mississippi Portal region. However, and with little surprise, adoption of GM cotton was more likely among YBFR in the Prairie Gateway (*PGATE*) and Southern Seaboard (*SSBOARD*) regions relative to the reference region (statistically significant at the 1% level). Thus, these farms are more likely to incorporate Bt cotton in their planted crop acres. Given that most farms in the Prairie Gateway and Southern Seaboard regions produce cotton, it would make intuitive sense for YBFR to want to employ inputs on their farm (Bt cotton) that increases profitability and reduces management time required for the cotton crop.

## Summary and Conclusions

The most recent farm bill placed an emphasis on assisting YBFR in overcoming the obstacles associated with starting and or continuing a new farming operation. As YBFR face forces largely out of their control, including limited access to credit and high land prices (often priced at its development value and not its food production value); one way that they can help control the profitability of their operation is through the adoption of genetically modified crops into their crop rotation. The adoption of genetically modified crops occurs because of cropping and production efficiency gains. In 2008, approximately 57 percent of the corn acreage and 92 percent of the soybean acreage were in GM varieties, while 59 percent of the cotton acreage was Bt cotton. The objective of this study was to examine the key farm, operator, regional, and household characteristics that influence the adoption of GM crops by YBFR. Understanding these factors will be critically important in designing extension and outreach activities that will make YBFR more comfortable with the adoption of GM crops into their operation, because they will no posses the requisite skill set necessary to make adoption profitable.

This study identifies factors that contribute to the adoption of GM crops by young and beginning farmers and ranchers (YBFR) in the U.S. A two-limit Tobit model regression analysis was used on data from the 2004-2006 Agricultural Resource Management Survey

(ARMS) to determine what characteristics influence the adoption of GM crops. Particular attention was given to the impact of adoption of Bt corn, Bt cotton, and HT soybeans. Results confirm a majority of our a priori expectations, as YBFR are more likely to adopt GM crops if they are not a full owner of the farm operation, as sales of the farm operation grow, if the crop is important to their region, and as they become more risk averse.

Surprisingly the results indicate that an additional year of education and off farm work experience negatively influences the adoption of GM crops. These results provide strong evidence for the need for tailored extension and outreach activities designed for highly educated YBFR with off farm employment. It is likely that this training should not focus on how adopting GM crops can increase the profitability of the operation, but on how to solve the technical problems associated with GM adoption, i.e., preventing herbicide drift and chemical contamination and identity preservation. Future research, should seek to understand and explore how adoption of GM crops affects the profitability of YBFR in the U.S., i.e., does the adoption of GM crops increase the net income of the operation relative to a farm that does not adopt GM crops as part of its rotation.

## Footnotes

[1] Genetically modified crops use genetic engineering techniques to derive seeds that are resistant to pests.

[2] With a growing rural population, many of whom are defined as "farmers" within the definitions, which apply to USDA's agricultural surveys ($1,000 in sales for a "normal" year); we obviously begin to find more "lifestyle" farmers. "Lifestyle" farmers have alternative farming goals. For example, as opposed to farming for profit, they may farm for other amenities of a rural lifestyle such clean air, less noise, open spaces, and less congestion. Combining these farmers with farmers who are in business to farm for profit is discordant. While the objective of this paper is not to look at the relationship between farm business goals and profitability, it is important to recognize that alternate goals exist within the group of farm operators selected for analysis.

[3] 100 percent of the land is rented for the group of farms falling under this classification.

[4] Assistance could be provided by extension agents and/or bankers. Johnson and Morehart (2006) conclude that to have a successful farming business the farm has to have a realistic business plan.

[5] Using the Heckman's technique, we tested the model for self-selection and found that the parameter was not significant.

[6] A rule of thumb among practitioners is that the regression model is deemed to have excellent predictive power if the computed value of McFadden Pseudo-R2 falls between 0.20 and 0.40.

[7] In a Tobit equation, each marginal effect includes both the influence of the explanatory variable on the probability of adoption as well as on the intensity of adoption. Thus, the total (marginal) effect takes into consideration that a change in an explanatory variable will affect simultaneously the number of adopters and the extent of adoption by both current and new adopters (Gould et al., 1989).

[8] Ratio of crop insurance premiums paid to total variable cost is used as a proxy for risk aversion. The notion being that higher the share of crop insurance premiums in total viable expenses, the higher the risk aversion.

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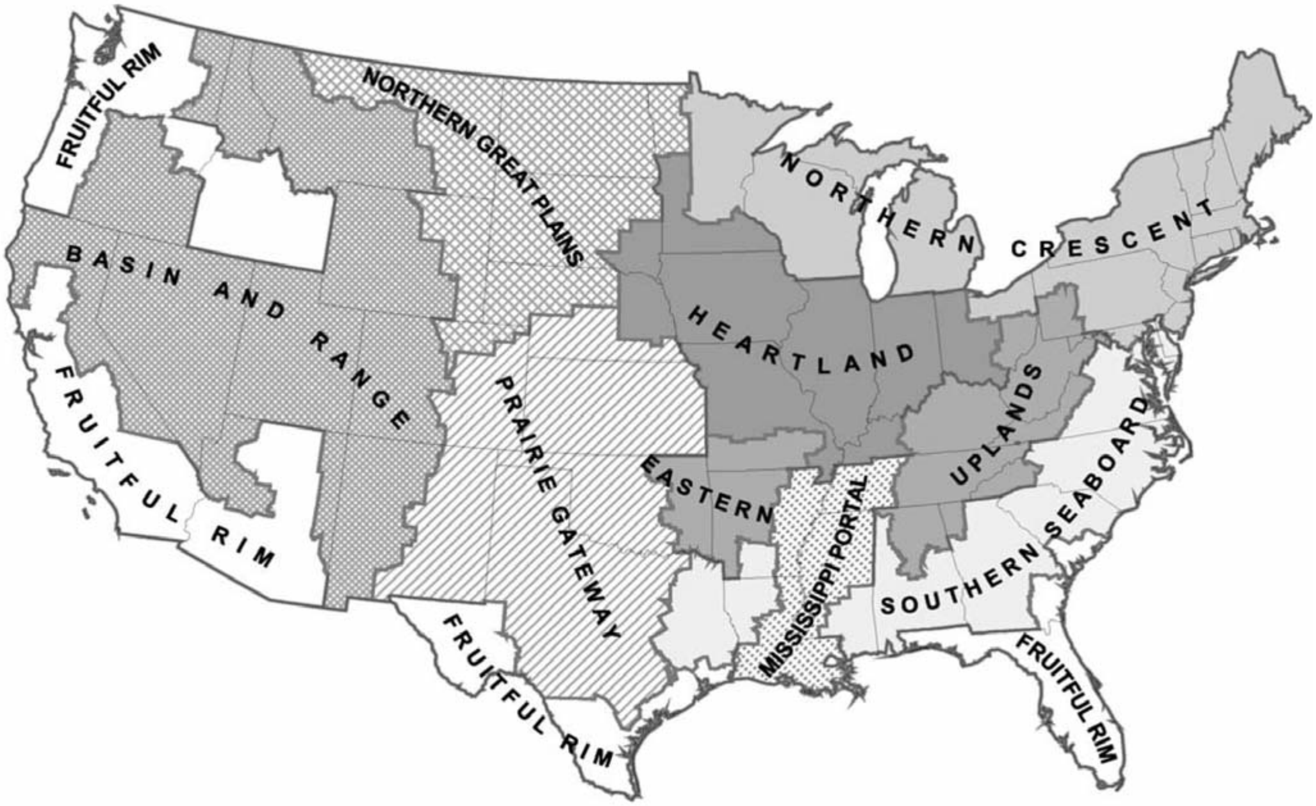
*Figure 1. U.S. farm resource regions*



Source: U.S. Department of Agriculture's Economic Research Service

*Table 1. Variable definition and summary statistics*

| **Variable** | **Mean** | **SD** |
|---|---|---|
| Operator's off farm work experience *(OPOWKEXP), years* | 27.04 | 14.59 |
| Operator's age *(EDUC)* | 12.96 | 1.75 |
| Operator's age (*AGE*) | 55.29 | 12.56 |
| Operator's age squared *(AGESQ)* | 3215.1 | 1428.4 |
| Farm Size =1 if farm sales are more than $500,000; 0 otherwise *(LARGE)* | 0.42 | 0.49 |
| Cropping efficiency (ratio of gross cash farm income to total variable costs) *(CROP_EFF)* | 2.82 | 26.15 |
| Risk aversion (ratio of crop/livestock insurance premiums to total variable cost) *(R_AVERSION)* | 0.0095 | 0.0359 |
| Tenant =1 if farm operator is tenant; 0 otherwise *(TENANT)* | 0.103 | 0.304 |
| Part-Owner =1 if farm operator is part-owner; 0 otherwise*(POWNER)* | 0.455 | 0.497 |
| Mean productivity index *(MEANPI)* | 78.74 | 6.22 |
| Farm is cash grain =1 if farm is classified as cash grain; 0 otherwise *(CGRAIN)* | 0.16 | 0.366 |
| Heartland region =1 if the farm is located in the Heartland region; 0 otherwise *(HEART)* | 0.13 | 0.33 |
| Northern Crescent region =1 if the farm is located in the Northern Crescent region; 0 otherwise *(NORTHC)* | 0.16 | 0.36 |
| Northern Great Plains region =1 if the farm is located in the Northern Great Plains region; 0 otherwise *(NORTHGP)* | 0.05 | 0.22 |
| Prairie Gateway region =1 if the farm is located in the Prairie Gateway region; 0 otherwise *(PGATE)* | 0.11 | 0.31 |
| Eastern Uplands region =1 if the farm is located in the Eastern Upland region; 0 otherwise *(EUPLAND)* | 0.11 | 0.31 |
| Southern Seaboard region =1 if the farm is located in the Heartland region; 0 otherwise *(SSBOARD)* | 0.14 | 0.35 |
| Fruitful Rim region =1 if the farm is located in the Fruitful region; 0 otherwise *(FRIM)* | 0.17 | 0.38 |
| Basin and Range region =1 if the farm is located in the Basin and Range region; 0 otherwise *(BASINR)* | 0.06 | 0.23 |
| Share of GM corn acres to total acres operated (%) | 3.83 | 11.4 |
| Share of GM soybean acres to total acres operated (%) | 5.75 | 15.72 |
| Share of GM cotton acres to total acres operated (%) | 1.96 | 10.24 |
| Sample size | 19638 | |

## Table 2. Characteristics of U.S. YBFR households and all other U.S. farm households

| Item | U.S. YBFR Households | All Other U.S. Farm Households |
|---|---|---|
| Number of farm | 412,321 | 1,632,583 |
| Percent of farms | 20.2 | 79.8 |
| ***Land:*** | *Acres per farm* | |
| Operated | 168 | 475 |
| Owned | 105 | 285 |
| Rented-in | 86 | 220 |
| Rented-out | 24 | 31 |
| ***Tenure:*** | *Percent* | |
| Full owner | 64.4 | 60.1 |
| Part owner | 24.8 | 34.7 |
| Tenant | 10.8 | 5.3 |
| ***Sales Class:*** | *Percent* | |
| $9,999 or less | 58.6 | 43.0 |
| $10,000-$99,999 | 33.5 | 39.8 |
| $100,000-$249,999 | 4.0 | 8.8 |
| $250,000-$499,999 | 1.7 | 4.7 |
| $500,000-$999,999 | 1.6 | 2.1 |
| $1,000,000 or more | 0.6 | 1.6 |
| ***Region:*** | *Percent* | |
| Northeast | 8.4 | 6.9 |
| Lake States | 8.2 | 10.7 |
| Corn Belt | 15.6 | 20.1 |
| Northern Plains | 6.2 | 9.1 |
| Appalachia | 15.0 | 13.6 |
| Southeast | 7.9 | 7.5 |
| Delta | 6.7 | 5.2 |
| Southern Plains | 18.2 | 14.1 |
| Mountain | 8.8 | 5.7 |
| Pacific | 5.0 | 7.0 |
| ***Farm Type:*** | *Percent* | |
| Cash grains and soybean | 10.7 | 17.1 |
| Other field crops | 20.5 | 18.6 |
| High value crops | 7.4 | 5.1 |
| Beef cattle | 31.9 | 39.5 |
| Hogs | Na | 1.9 |
| Dairy | 1.5 | 3.7 |
| Poultry | 1.6 | 2.3 |
| General livestock | 25.4 | 11.8 |
| ***Technology adoption:*** | *Percent* | |
| Use of GMO crops (corn/soybean) | 15.2 | 18.4 |
| Have written business plans | 13.6 | 7.1 |
| ***Farm household income:*** | *Dollars* | |
| Net farm income | 2,839 | 15,772 |
| Off-farm income | 80.397 | 63,667 |
| Earned income[a] | 65,870 | 44,390 |
| Unearned income[b] | 14,527 | 19,277 |
| Average household income | 83,236 | 79,439 |
| ***Off-farm Work Decisions:*** | *Percent* | |
| Operator works off-farm | 23.4 | 18.5 |
| Spouse works off-farm | 8.6 | 12.6 |
| Both operator and spouse work off-farm | 50.9 | 28.3 |
| Neither works off-farm | 17.1 | 40.6 |
| ***Operator Education level:*** | *Percent* | |
| Less than high school | 10.1 | 15.6 |
| High school or GED | 59.0 | 60.8 |
| Some college | 30.9 | 23.6 |

[a] Includes wage and salary income of operators and spouses and off-farm business income.
[b] Includes income from interest dividends accounts, retirement accounts and public assistance
Source: Agricultural and Resource Management Survey, 2006.

*Table 3. Tobit estimates of adoption-decision model of GM corn, cotton, and soybeans, 2004-2006*

| Variables | Corn | | Cotton | | Soybean | |
|---|---|---|---|---|---|---|
| | Par Est. | dy/dx | Par Est. | dy/dx | Par Est. | dy/dx |
| Intercept | -0.5584*** | - | -2.2557*** | - | -0.4738*** | - |
| | (0.0939) | - | (0.3165) | - | (0.1141) | - |
| Operator's off farm work experience *(OPOWKEXP)* | -0.003*** | -0.0005*** | -0.0113*** | -0.0009*** | -0.0022*** | -0.0004*** |
| | (0.0007) | (0.0002) | (0.0035) | (0.0003) | (0.0007) | (0.0001) |
| Operator's education *(EDUC)* | -0.0021 | -0.0004 | 0.0267*** | 0.002*** | -0.0146*** | -0.0022*** |
| | (0.0026) | (0.0005) | (0.0088) | (0.0007) | (0.0029) | (0.0005) |
| Operator's age *(AGE)* | -0.0039* | -0.0007* | -0.0074 | -0.0006 | -0.0023 | -0.0004 |
| | (0.0023) | (0.0004) | (0.0082) | (0.0006) | (0.0025) | (0.0004) |
| Operator's age squared *(AGESQ)* | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| | (0.0001) | (0) | (0.0001) | (0.0001) | (0.0001) | (0) |
| Dummy for farm sales of more than $500,000 *(LARGE)* | 0.1911*** | 0.0329*** | 0.7012*** | 0.0531*** | 0.1289*** | 0.0196*** |
| | (0.0089) | (0.0016) | (0.0372) | (0.0027) | (0.0096) | (0.0015) |
| Cropping efficiency (ratio of gross cash farm income to total variable costs) *(CROP_EFF)* | -0.007** | -0.0012** | -0.0194** | -0.0015** | -0.0012 | -0.0002 |
| | (0.0029) | (0.0005) | (0.0086) | (0.0007) | (0.0013) | (0.0002) |
| Risk aversion (ratio of crop/livestock insurance premiums to total variable cost) *(R_AVERSION)* | 0.5668*** | 0.0944*** | 2.0895*** | 0.1544*** | 0.4642*** | 0.0691*** |
| | (0.1692) | (0.0282) | (0.7632) | (0.0567) | (0.1547) | (0.0231) |
| Tenant *(TENANT)* | 0.1613*** | 0.03*** | 1.0733*** | 0.0921*** | 0.2681*** | 0.047*** |
| | (0.0156) | (0.0032) | (0.0649) | (0.0056) | (0.0176) | (0.0035) |
| Part-Owner *(POWNER)* | 0.204*** | 0.0347*** | 0.7958*** | 0.0597*** | 0.2527*** | 0.0385*** |
| | (0.0107) | (0.0018) | (0.0565) | (0.0038) | (0.0125) | (0.0019) |
| Mean productivity index *(MEANPI)* | -0.0001 | -0.0001 | -0.0041 | -0.0003 | 0.0012 | 0.0002 |
| | (0.0008) | (0.0002) | (0.0025) | (0.0002) | (0.001) | (0.0002) |
| Farm is cash grain *(CGRAIN)* | 0.2612*** | 0.0508*** | -0.1944*** | -0.0141*** | 0.5925*** | 0.1224*** |
| | (0.0111) | (0.0025) | (0.0443) | (0.0031) | (0.0121) | (0.0033) |
| Farm located in Heartland region *(HEART)* | 0.3512*** | 0.0736*** | -0.6994*** | -0.047*** | 0.112*** | 0.0178*** |
| | (0.0179) | (0.0046) | (0.0802) | (0.0048) | (0.0145) | (0.0025) |
| Farm located in Northern Crescent region *(NORTHC)* | 0.3253*** | 0.066*** | - | - | -0.0469*** | -0.0069*** |
| | (0.018) | (0.0043) | - | - | (0.015) | (0.0022) |
| Farm located in Northern Great Plains region *(NORTHGP)* | 0.0813*** | 0.0144*** | - | - | -0.3009*** | -0.0372*** |
| | (0.0245) | (0.0046) | - | - | (0.0273) | (0.0028) |
| Farm located in Prairie Gateway region *(PGATE)* | 0.1195*** | 0.0216*** | 0.2033*** | 0.0155*** | -0.2925*** | -0.0372*** |
| | (0.0204) | (0.004) | (0.0447) | (0.0035) | (0.0216) | (0.0024) |
| Farm located in Eastern Uplands region *(EUPLAND)* | 0.0985*** | 0.0175*** | -0.3582*** | -0.0252*** | -0.2128*** | -0.0282*** |
| | (0.0211) | (0.004) | (0.0693) | (0.0046) | (0.0221) | (0.0027) |
| Farm located in Southern Seaboard region *(SSBOARD)* | 0.08*** | 0.014*** | 0.3434*** | 0.0266*** | -0.0401** | -0.0059** |
| | (0.0197) | (0.0036) | (0.038) | (0.0031) | (0.0166) | (0.0024) |
| Farm located in Fruitful rim region *(FRIM)* | -0.0394* | -0.0065* | -0.2337*** | -0.0168*** | - | - |
| | (0.0218) | (0.0035) | (0.0489) | (0.0034) | - | - |
| Farm located in Basin and Range region *(BASINR)* | -0.0514 | -0.0083* | - | - | -0.0054 | -0.0008 |
| | (0.032) | (0.005) | - | - | (0.0123) | (0.0019) |
| Year dummy for 2004 *(Y04)* | -0.0433*** | -0.0072*** | -0.0082 | -0.0007 | 0.0258** | 0.0039** |
| | (0.0101) | (0.0017) | (0.0371) | (0.0028) | (0.0117) | (0.0018) |
| Year dummy for 2005 (Y05) | -0.0504*** | -0.0083*** | 0.0815** | 0.0061** | -0.0054 | -0.0008 |
| | (0.0105) | (0.0017) | (0.0366) | (0.0028) | (0.0123) | (0.0019) |
| Log pseudo-likelihood | -4824.8311 | | -2781.2538 | | -4431.2378 | |
| Pseudo $R^2$ | 0.3302 | | 0.2412 | | 0.4776 | |
| Sample Size | 19,638 | | 19,638 | | 19,638 | |

Numbers in parentheses are standard errors.
* Significant at 10%; ** significant at 5%; ***significant at 1%