

A Binary Logit Analysis of Factors Impacting Adoption of Genetically Modified Cotton

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Agricultural Resource Management Survey (ARMS) data for 2003 were used to estimate two binary logit models for two definitions of genetically modified (GM) cottonseed adoption: one in which adoption of either *Bacillus thuringiensis* (Bt) or herbicide-resistant (HR) cottonseed was considered GM cottonseed adoption, and another in which adoption of Bt, HR, or stacked-gene (SG) cottonseed was considered GM cottonseed adoption. Results indicate conservation tillage did not positively affect adoption of GM cottonseed with either of these definitions, while adoption of GM cottonseed in the previous year did. Conventional, non-GM cottonseed, used as “refuge,” also did not affect these adoption decisions for the study year.

Key words: Agricultural Resource Management Survey (ARMS), binary logit model, conservation tillage, cotton, genetically modified seed, herbicide-resistant cotton, jackknife procedure, refuge cotton, stacked-gene cotton, technology adoption.

Introduction

Upon the commercial introduction of *Bacillus thuringiensis* (Bt) cotton in 1996, the US Environmental Protection Agency mandated an Insect Resistance Management (IRM) program for the purpose of preserving the benefits of this technology’s insect protection by delaying resistance. According to that mandate, growers planting Bt cotton were required to follow the IRM practices designed to keep some lepidopteran populations from being exposed to the Bt protein. Thus, a refuge of conventional, non-Bt cotton had been planted along with Bt cotton. Other than Bt (insect-resistant) cotton, genetically modified (GM) types of cotton include herbicide-resistant (HR) and stacked-gene (SG), the latter combining the traits of insect resistance with herbicide resistance.

On another front, conservation tillage—and no-till practices in particular—has increased over the past few years (Figures 1 and 2). Conservation tillage (either no-till or reduced tillage) is reported to reduce soil erosion by preventing reduction in crop residue on the soil surface (Harper, 1996). Yet, despite the apparent advantages of conservation-tillage (CT) practices in reducing soil erosion, soil degradation, runoff, and in improving soil quality (Edwards, 1995; Sandretto, 1997), some farmers adopt no-till or minimum-till, and others do not adopt CT practices at all.

The use of CT practices may be even more important in cotton production than in other row crop production because of the minimal amount of residue left on the soil surface. Crop residues after planting averages 3% for cotton compared with 29% for corn (US Department of Agriculture [USDA], 1997). The use of HR or

SG seed technology indirectly reduces the use of residual herbicides and increases profit potential of the farmer (Marra, Pardey, & Alston, 2003).

Past studies have attempted to show the relationship between adoption of GM—specifically HR—seed and conservation tillage and to determine the causal effects between them. For example, Fernandez-Cornejo and McBride’s (2002) cross-sectional study using USDA’s Agricultural Resource Management Survey (ARMS) data for 1997 investigated a potential simultaneous relationship between HR soybean seed and CT practices using two simultaneously estimated binomial probit models; the study compared those results with two single-equation probit models. Their study suggested that accounting for simultaneity was important for the no-till decision but not for the seed-use decision. In a more recent study with time-series data for 1992-2004, Roberts, English, Gao, and Larson (2006) used a Bayesian analysis and a two-equation simultaneous logit analysis to ascertain that introduction of HR cottonseed in Tennessee increased the probability that farmers would adopt conservation tillage, and farmers who had previously adopted CT practices were more likely to adopt HR cottonseed. They concluded that the simultaneous adoption of conservation tillage and HR cottonseed reduced soil erosion and residual herbicide use, as well as increased profit. However, with ARMS data for 2003, Banerjee et al. (2007) found no evidence of a simultaneous relationship between these two adoption decisions.

The overall objective of this study is to identify factors that led to the adoption of GM cotton in the United States. Specifically, the study seeks to identify farm and

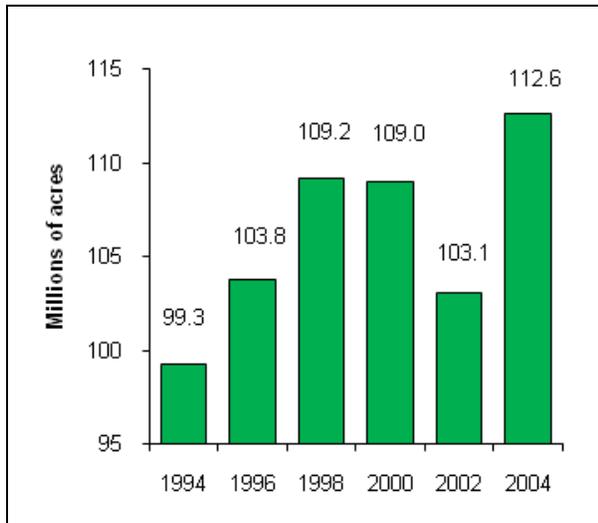


Figure 1. Conservation-tillage adoption in the United States, 1994-2004.

Source: Conservation Technology Information Center.

farmer characteristics driving the production of GM cotton in the United States in general. In particular, it studies the impact (or otherwise) of conservation tillage (i.e., no-till and reduced till: ridge-till, strip-till, and mulch-till) and conventional cotton used as refuge on the adoption of GM cottonseed across the United States and within selected regions.

Data and Methods

This study used two definitions of genetic modification of cottonseed adoption: one in which adoption of either Bt or HR cottonseed was considered as GM cottonseed adoption (denoted as BH); and another in which adoption of Bt, HR, or SG cottonseed adoption was considered as GM cottonseed adoption (denoted as BHS). The survey respondents were classified as adopters of a particular type of GM cotton according to these definitions. The “yes” responses received for these definitions (as percentages of the sample used in the regressions) were 65% and 86%, respectively. Two single-equation binary logit models (Maddala, 1983) were estimated using the same set of independent variables, except for the relevant adoption variable.

The ARMS is a random sample of cotton farms across the United States. The USDA Economic Research Service (ERS) used data from the 2003 ARMS—particularly the Cotton Production Practices and Costs Report and the Cotton Costs and Returns Report—to estimate the two binary logit models with the two definitions of genetic modification. The dependent

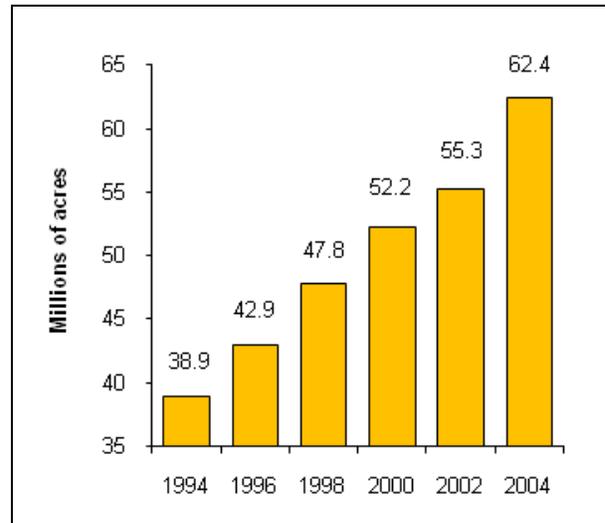


Figure 1. No-till adoption in the United States, 1994-2004.

Source: Conservation Technology Information Center.

variable for each equation indicated the adoption of GM cotton vis-à-vis its non-adoption (i.e., adoption of conventional cotton). The explanatory variables for each equation included

1. demographic information of the survey respondents/farmers: age, education level, gross annual farm income, and length of tenure in cotton farming;
2. farm characteristics: farm size, farm labor expense, refuge size in field surveyed, percentage of farm acres in cotton, if they grew genetically engineered cotton in the previous year (2002), if any part of their surveyed field was declared “highly erodible land” (HEL) by the Natural Resources Conservation Service (NRCS), if they no-tilled in 2002, cotton acres harvested, and percentage of cotton acres harvested using one or more CT equipment; and
3. region-specific dummy variables: one for each cotton-producing region, with the 17 cotton-producing states being divided into five regions.

The logit equation is written as (Greene, 1993)

$$\Pr(Y = 1) = \frac{e^{\beta'x}}{1 + e^{\beta'x}}, \tag{1}$$

with the cumulative distribution function given by

$$F(\beta'x) = \frac{1}{1 + e^{-\beta'x}}, \tag{2}$$

where β' represents the vector of parameters associated with the factors x .

Assuming the probability that farmer n will choose to produce cotton using a particular technology (BH or BHS seed) is equal to the proportion of cotton farmers using that technology, the individual empirical models to be estimated may be specified as

$$\begin{aligned}
 BH = & \beta_0 + \beta_1 CONSTILL + \beta_2 BH02 + \beta_3 LABEXP \\
 & + \beta_4 CTA + \beta_5 CTP + \beta_6 HEL + \beta_7 REFUGE \\
 & + \beta_8 YIELD + \beta_9 PNT + \beta_{10} AGE + \beta_{11} EDU \\
 & + \beta_{12} TEN + \beta_{13} GFI + \sum_{j=14}^{17} \beta_j REGION_j + \varepsilon_T, \quad (3)
 \end{aligned}$$

$$\begin{aligned}
 BHS = & \gamma_0 + \gamma_1 CONSTILL + \gamma_2 BHS02 + \gamma_3 LABEXP \\
 & + \gamma_4 CTA + \gamma_5 CTP + \gamma_6 HEL + \gamma_7 REFUGE \\
 & + \gamma_8 YIELD + \gamma_9 PNT + \gamma_{10} AGE + \gamma_{11} EDU \\
 & + \gamma_{12} TEN + \gamma_{13} GFI + \sum_{j=14}^{17} \gamma_j REGION_j + \varepsilon_G, \quad (4)
 \end{aligned}$$

where

CONSTILL = dummy variable indicating whether or not CT practices were adopted;

BH02 = dummy variable indicating if Bt or HR cotton was grown in the prior year, 2002;

BHS02 = dummy variable indicating if Bt, HR, or SG cotton was grown in the prior year, 2002;

LABEXP = total labor expense on the farm (\$100,000);

CTA = total harvested cotton acres (dryland and irrigated) on the farm (100 acres);

CTP = percentage of cotton acres on the farm;

HEL = dummy variable indicating if NRCS classified any part of the field surveyed as HEL;

REFUGE = dummy indicating if conventional, refuge cotton was used in the survey year, 2003;

YIELD = lint yield in pounds per acre harvested or expected in 2003;

PNT = dummy variable indicating if no-till was used in the surveyed field in the year before the survey, 2002;

AGE = age of the principal farm operator;

EDU = dummy variable indicating the surveyed farm operator's education level (whether or not college graduate);

TEN = length of tenure (in years) of the operator household for the surveyed field;

GFI = gross farm income in 2003 (\$100,000);

REGION = set of four dummies:

REGION1 includes Alabama, Florida, and Georgia; *REGION2* includes North Carolina, South Carolina, and Virginia;

REGION3 includes Arkansas, Louisiana, Mississippi, Missouri, and Tennessee and is excluded as the reference region to compare other regions with;

REGION4 includes Texas, Oklahoma, and Kansas;

REGION5 includes Arizona, California, and New Mexico; with

ε_T and ε_G = random error terms;

β 's and γ 's = parameters to be estimated; and

the subscript n for the n^{th} farmer is suppressed for clarity.

The adoption of CT practices was expected to positively influence the adoption of GM cotton. Fields in states with more HEL acres would likely demonstrate a higher probability of adoption of GM cotton than states with less HEL acres. However, due to the classification of states into regions, no *a priori* signs could be assigned to the regional dummies. All other variables except *AGE* were expected to have positive coefficients. Tables 1 and 2 provide detailed definitions of all explanatory variables used in estimating the regression Equations 3 and 4, respectively, and the relevant summary statistics.

To determine the quantitative effects of the right-side variables on each technology, marginal effects were calculated. Marginal effects (Greene, 1993; Maddala, 1983) measure changes in the probability of adopting each technology due to given changes in the relevant explanatory variables (Liao, 1994; Long, 1997). Marginal effects of continuous variables were calculated at the means of the data.¹ For dummy variables, a value of 0 was used if the mean was less than 0.5, and a value of 1 was used if the mean was greater than or equal to 0.5 (Obubuafo, Gillespie, Paudel, & Kim, 2006; Schlotzhauer, personal communication, 2006).²

1. In sufficiently "large samples," marginal effects calculated by averaging the individual marginal effects at each observation (Bell, Roberts, English, & Park, 1994; Neter, Wasserman, & Kutner, 1983; Pindyck & Rubinfeld, 1976) would give the same results as obtained here from the means of the data (Greene, 1993, p. 876) by adding an observation with all means and calculating the marginal effects at that point.
2. Anderson and Newell (2003) have developed a novel way of simplifying the calculation of marginal effects in logit and probit models (making them a function of only the estimated constant term) and their associated asymptotic variances by normalizing the explanatory variables at any desired value.

Table 1. Summary of variables used in the logit model for Bt/herbicide-resistant (BH) cottonseed.^a

Explanatory variable	Definition (Frequency used in regression) ^b	Mean (Std. dev.)
Farm characteristics		
CONSTILL	If practiced conservation tillage (no-till, ridge-till, strip-till, and mulch-till), i.e., if used one or more CT equipment (Yes = "1" = 133 in sample ≈ 2,270 in population; No = "0" = 404 in sample ≈ 6,859 in pop.)	0.25
BH02	If used Bt or HR cottonseed in the prior year, 2002 (Yes = "1" = 333 in sample ≈ 5,662 in pop.; No = "0" = 204 ≈ 3,466 in pop.)	0.10
LABEXP	Labor expense per cotton farm in 2003 in US dollars, scaled by 100,000s	0.43 (0.09)
CTA	Cotton acres (dryland & irrigated) harvested on farm on average in 2003, scaled by 100s	6.16 (0.23)
CTP	Percentage of cotton acres harvested on farm in 2003	0.72 (0.01)
HEL	If NRCS ^d classified any part of the field surveyed "highly erodible land (HEL)" (Yes = "1" = 110 in sample ≈ 1,876 in pop.; No = "0" = 427 in sample ≈ 7,252 in pop.)	0.21
REFUGE	Percentage of field used as refuge to comply with IRM guidelines	1.08 (0.38)
YIELD	Lint yield harvested or expected in 2003 in pounds per acre	567.09 (38.07)
PNT	If previously 'no-tilled' (i.e., soil and previous crop residue left undisturbed from harvest to planting) in Spring/Summer 2002 (Yes = "1" = 73 in sample ≈ 1,234 in pop.; No = "0" = 464 in sample ≈ 7,895 in pop.)	0.14
Farmer characteristics		
AGE	Age (during survey in 2003) in years	54.65 (0.87)
EDU	If college graduate (Yes = "1" = 137 in sample ≈ 2,322 in pop.; No = "0" = 400 in sample ≈ 6,807 in pop.)	0.25
TEN	Length of tenure (in field surveyed in 2003) of principal operator in years	17.35 (0.92)
GFI	Estimated pre-tax gross farm income of respondent in 2003 in US \$, scaled by 100Ks	4.52 (0.37)
Farm location (REGION)^e		
REGION1	If farm is located in Region 1 (Yes = "1" = 81 in sample ≈ 1,370 in pop.; No = "0" = 456 in sample ≈ 7,758 in pop.)	0.15
REGION2	If farm is located in Region 2 (Yes = "1" = 47 in sample ≈ 792 in pop.; No = "0" = 490 in sample ≈ 8,336 in pop.)	0.09
REGION4	If farm is located in Region 4 (Yes = "1" = 304 in sample ≈ 5163 in pop.; No = "0" = 233 in sample ≈ 3,965 in pop.)	0.57
REGION5	If farm is located in Region 5 (Yes = "1" = 44 in sample ≈ 740 in pop.; No = "0" = 493 in sample ≈ 8,388 in pop.)	0.08

^a Total number of observations, *N* (BH) = 537 respondents in sample ≈ 9,128 farms in the population (using the NASS "full-sample weight" variable). Dependent variable (BH), if used Bt or herbicide-resistant cottonseed: Yes = "1" = 349 in sample ≈ 5,342 in population; No = "0" = 188 in sample ≈ 3,786 in population (population mean = 0.65).

^b Except age and location, all other variables were hypothesized to have positive signs on their estimated coefficients. Age was expected to have a negative sign, and the signs of the location variables could not be hypothesized a priori, since it was difficult to speculate on reasons for differences among regions.

^c Standard deviation of 'continuous' variable. Means are from the expanded full sample, and standard deviations use the NASS delete-a-group jackknife procedure.

^d Natural Resources Conservation Service.

^e The dummy variable for Region 3 (AR, LA, MS, MO, TN), with 63 observations in sample ≈ 1,062 observations in population of "yes" (population mean = 0.12), was omitted. This facilitates comparison of adoption probabilities in Region 3 with the other four regions: Region 1 (AL, FL, GA), Region 2 (NC, SC, VA), Region 4 (KS, OK, TX), and Region 5 (AZ, CA, NM).

The ARMS uses a complex stratified, multiphase, nonrandom survey design that may render naïve standard errors obtained by classical statistical algorithms invalid insofar as inferences on point estimates are concerned. Each observation in the ARMS represents a number of similar farms based on factors such as land

use, farm size, etc.; the particular number is the survey weight or survey expansion factor. In effect, this is the inverse of the probability that the surveyed farm is selected to be surveyed (El-Osta, Mishra, & Morehart, 2007, p. 292). In order to alleviate the possibility of such a bias in measurement, the National Agricultural Statis-

Table 2. Summary of variables used in the logit model for Bt/herbicide-resistant/stacked-gene (BHS) cottonseed.^a

Explanatory variable	Definition (Frequency used in regression) ^b	Mean (Std. dev.)
Farm characteristics		
CONSTILL	If practiced conservation tillage (no-till, ridge-till, strip-till, and mulch-till), i.e., if used one or more conservation-tillage equipment (Yes = "1" = 266 in sample ≈ 3,585 in population; No = "0" = 632 in sample ≈ 8,541 in pop.)	0.30
BHS02	If used Bt, herbicide-resistant, or stacked-gene cottonseed in the prior year, 2002 (Yes = "1" = 639 in sample ≈ 8,632 in pop.; No = "0" = 259 ≈ 3,494 in pop.)	0.71
LABEXP	Labor expense per cotton farm in 2003 in US dollars, scaled by 100,000s	0.45 (0.07)
CTA	Cotton acres (dryland and irrigated) harvested on farm on average in 2003, scaled by 100s	6.70 (0.21)
CTP	Percentage of cotton acres harvested on farm in 2003	0.71 (0.01)
HEL	If NRCS ^d classified any part of the field surveyed "highly erodible land (HEL)" (Yes = "1" = 159 in sample ≈ 2,145 in pop.; No = "0" = 739 in sample ≈ 9,981 in pop.)	0.18
REFUGE	Percentage of field used as refuge to comply with IRM guidelines	1.53 (0.49)
YIELD	Lint yield harvested or expected in 2003 in pounds per acre	647.90 (31.79)
PNT	If previously 'no-tilled' (i.e., soil and previous crop residue left undisturbed from harvest to planting) in Spring/Summer 2002 (Yes = "1" = 166 in sample ≈ 2,243 in pop.; No = "0" = 732 in sample ≈ 9,884 in pop.)	0.18 (0.01)
Farmer characteristics		
AGE	Age (during survey in 2003) in years	54.19 (0.74)
EDU	If college graduate (Yes = "1" = 227 in sample ≈ 3,068 in pop.; No = "0" = 671 in sample ≈ 9,059 in pop.)	0.25
TEN	Length of tenure (in field surveyed in 2003) of principal operator in years	17.80 (0.75)
GFI	Estimated pre-tax gross farm income of respondent in 2003 in US \$, scaled by 100Ks	5.29 (0.29)
Farm location (REGION)^e		
REGION1	If farm is located in Region 1 (Yes = "1" = 146 in sample ≈ 1,976 in pop.; No = "0" = 752 in sample ≈ 10,151 in pop.)	0.16
REGION2	If farm is located in Region 2 (Yes = "1" = 95 in sample ≈ 1,276 in pop.; No = "0" = 803 in sample ≈ 10,850 in pop.)	0.11
REGION4	If farm is located in Region 4 (Yes = "1" = 391 in sample ≈ 5,285 in pop.; No = "0" = 507 in sample ≈ 6,841 in pop.)	0.44
REGION5	If farm is located in Region 5 (Yes = "1" = 62 in sample ≈ 835 in pop.; No = "0" = 836 in sample ≈ 11,291 in pop.)	0.07

^a Total number of observations, *N* (BHS) = 898 respondents in sample ≈ 12,126 farms in the population (using the NASS "full-sample weight" variable). Dependent variable (BHS), if used Bt or herbicide-resistant or stacked-gene cottonseed: Yes = "1" = 769 in sample ≈ 9,163 in population; No = "0" = 129 in sample ≈ 2,963 in population (population mean = 0.86).

^b Except age and location, all other variables were hypothesized to have positive signs on their estimated coefficients. Age was expected to have a negative sign, and the signs of the location variables could not be hypothesized a priori, since it was difficult to speculate on reasons for differences among regions.

^c Standard deviation of 'continuous' variable. Means are from the expanded full sample, and standard deviations use the NASS delete-a-group jackknife procedure.

^d Natural Resources Conservation Service.

^e The dummy variable for Region 3 (AR, LA, MS, MO, TN), with 204 observations in sample ≈ 2,754 observations in population of "yes" (population mean = 0.23), was omitted. This facilitates comparison of adoption probabilities in Region 3 with the other four regions: Region 1 (AL, FL, GA), Region 2 (NC, SC, VA), Region 4 (KS, OK, TX), and Region 5 (AZ, CA, NM).

tics Service (NASS) has established standards that allow valid inferences based on the entire population. These standards were used in this analysis. In particular, "full-sample weights" were used to calculate means, parameter estimates, and marginal effects, and "replicate

weights" were used in the "delete-a-group jackknife" procedure to calculate variances and, hence, standard deviations of all point estimates (Ahearn, El-Osta, & Deewbre, 2006; Dubman, 2000; El-Osta, Mishra, & Ahearn, 2004; El-Osta, Mishra, & Morehart, 2007; Kott,

Table 3. Parameter estimates and marginal effects from the single-equation logit models for Bt/herbicide-resistant (BH) and Bt/herbicide-resistant/stacked-gene (BHS) cottonseed.

Explanatory variable ^a	BH cottonseed equation		BHS cottonseed equation	
	Parameter estimate	Marginal effect ^b	Parameter estimate	Marginal effect ^b
Constant *	-3.311 (1.648) ^c		-4.717 (1.898) ^c	
CONSTILL *	-1.030 (0.550)	-0.116 (0.062) ^d	-0.639 (0.952)	<-0.001 (<0.001) ^d
BH02***	4.615 (0.520)	0.519 (0.058)	7.906 (1.516)	0.002 (<0.001)
LABEXP	-0.022 (0.147)	-0.003 (0.017)	-0.718 (0.706)	<-0.001 (<0.001)
CTA	-0.068 (0.052)	-0.008 (0.006)	-0.054 (0.081)	<-0.001 (<0.001)
CTP***	2.486 (0.744)	0.280 (0.084)	4.285 (1.090)	0.001 (<0.001)
HEL	-0.453 (0.812)	-0.051 (0.091)	-0.467 (1.490)	<-0.001 (<0.001)
REFUGE	-0.050 (0.042)	-0.006 (0.005)	0.618 (4.365)	<0.001 (0.001)
YIELD	<-0.001 (<0.001)	<-0.001 (<0.001)	<-0.001 (0.002)	<-0.001 (<0.001)
PNT*	1.124 (0.631)	0.126 (0.071)	0.975 (1.300)	<0.001 (0.001)
AGE	0.021 (0.014)	0.002 (0.002)	0.040 (0.042)	<0.001 (0.001)
EDU	-0.264 (0.473)	0.030 (0.053)	-1.340 (0.800)	<-0.001 (<0.001)
TEN	-0.019 (0.016)	-0.002 (0.002)	-0.042 (0.049)	<-0.001 (<0.001)
GFI	0.017 (0.059)	0.002 (0.007)	0.068 (0.134)	<0.001 (0.001)
REGION1 ^{e**}	-1.539 (0.778)	-0.173 (0.087)	-2.115 (1.721)	<-0.001 (0.001)
REGION2	-1.139 (0.696)	-0.128 (0.078)	3.089 (14.838)	<0.001 (0.004)
REGION4	-0.309 (0.771)	-0.035 (0.087)	-1.407 (1.322)	<-0.001 (0.001)
REGION5	0.188 (0.665)	0.021 (0.075)	-1.445 (1.529)	<-0.001 (0.001)
Log likelihood	-5,607.622		-10,566.661	
McFadden R ²	0.4527		0.7835	
Adjusted McFadden R ²	0.4513		0.7823	
Prediction success:				
Concordant	85.3%		96.3%	
Discordant	14.5%		2.1%	
Tied	0.2%		1.5%	
Number of observations	537 in sample ≈ 9,128 farms in expanded full sample		898 in sample ≈ 12,126 farms in expanded full sample	
Number of adopters	349 in sample ≈ 5,342 farms in expanded full sample		769 in sample ≈ 9,163 farms in expanded full sample	

Note: ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

^a Explanatory variables are defined in Table 1.

^b A marginal effect indicates the change in predicted probability of adopting the relevant technology for a unit change in an explanatory variable. Marginal effects of continuous variables were calculated at the means of the data. For dummy variables, a value of 0 was used if the mean was less than 0.5 and a value of 1 if the mean was greater than or equal to 0.5.

^c Numbers in parentheses below parameter estimates are respective asymptotic delete-a-group jackknife standard errors of those estimates. Parameter estimates were obtained using the NASS "full-sample weight" variable.

^d Numbers in parentheses below marginal effects are respective asymptotic delete-a-group jackknife standard errors of those effects. Marginal effects were obtained using the NASS "full-sample weight" variable.

^e Regional dummy variables compare adoption relative to cotton farmers in Region 3 (AR, LA, MS, MO, TN).

1997a, 1997b; Lambert, Sullivan, & Claasen, 2007; Lohr, 1999). The samples used in the analysis included 537 and 898 respondents, respectively, for BH and BHS technologies, which, when properly expanded using survey weights, yielded a population of 9,128 and 12,126 farm operator households, respectively (Tables 1 and 2).

Results

Results (as given by the maximum likelihood estimates from Equations 3 and 4) indicate conservation tillage (*CONSTILL*) did not affect adoption of GM cotton with either definition for the study year (2003) at the 5% level; however, it did seem to cause a reduction in the likelihood of BH adoption (Equation 3) at the 10% level

(Table 3). The latter counter-intuitive result brings to light one of the issues regarding the use of cross-sectional data. Instead of establishing causality, effects, determinants, or impacts, our regression results may be read as implying correlations, relationships, and associations. The “correlations” presented, however, assume *ceteris paribus* conditions. The weak negative correlation becomes weaker and no more significant even at the 10% level when SG cotton adopters are included in the mix, as apparent from the BHS adoption model (Equation 4) estimation. It is plausible that farmers who had not adopted CT practices before the introduction of BH seed might have first adopted BH seed and then decided that they could improve efficiency by adopting CT practices sometime during or before 2003. A similar study in a later year might make this variable positive and significant.

Whether GM cotton was used in the prior year (2002) positively affected the adoption of GM cotton in the study year at the 1% level, using both definitions. Percentage of cotton acres on the farm (*CTP*) also positively affected both adoption decisions at the 1% level. The variable for Region 1 was significant at the 5% level and negative in the BH equation, with a marginal effect of -0.173. This indicates that, estimated in isolation, this region (southeastern states of AL, FL, and GA) was 17.3% less likely to adopt BH relative to cotton farmers in Region 3 (AR, LA, MS, MO, TN).

Previous experience of no-till (*PNT*) in the BH equation and education level (*EDU*) in the BHS equation were significant only at the 10% level, with *EDU* having an unexpected negative sign.

Labor expense, cotton acres on farm, *HEL*, refuge size, yield, tenure, gross farm income, and age were not significant factors in determining adoption of GM technologies in cotton production for the study year.

Conclusions

Recent studies involving adoption of CT practices and HR cotton have attempted to determine if the adoption of CT practices impacts the adoption of GM cottonseed and/or vice versa. If CT adoption impacts GM cottonseed adoption, then adoption of CT practices can indirectly affect residual herbicide use and farm profits. The current study using cross-sectional ARMS data does not provide strong evidence of such a correlation with either of the two definitions of genetic modification used. Refuge (conventional, non-GM) cotton also did not affect GM cottonseed adoption using any definition in this study. However, the limitations of a cross-sectional

study using complex data such as from the ARMS are apparent.

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