Journal of Agricultural and Applied Economics, 39,3(December 2007):657–669

Effects of Seed and Farm Characteristics on Cottonseed Choice: A Choice-Based Conjoint Experiment in the Mississippi Delta

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Producers' preferences for cottonseed with respect to price, seed type, yield, and fiber quality are examined by a willingness-to-pay approach via mail surveys. Results indicate a positive willingness to pay (WTP) for technology relative to conventional cottonseed, and WTP increases with the level of technology. Yield and quality also show a positive WTP. Larger farms have a higher WTP for technology, and farms with more farm labor have a lower WTP for technology. These results suggest economies of size in technology adoption (biotechnology is not size-neutral) and that labor and biotechnology are direct substitutes.

Key Words: biotechnology, conjoint analysis, conjoint (choice) experiment, cotton, farm labor, farm size, fiber quality, willingness to pay (WTP)

JEL Classifications: D24, Q12, Q16

The United States produced a record 23.25 million bales of cotton in 2004, over 25% more than the 2003 crop. Yield was a record 855 pounds, 125 pounds above the previous record of 730 pounds established in 2002 (USDA 2006a). Record production set the stage for low prices. At the same time, more than two thirds of U.S. cotton is now marketed in the world export market. Thus, U.S. producers must strive to produce high-quality cotton that meets international fiber characteristic demands. Cotton importers desire cotton that is longer in fiber and more uniform than U.S. base grade cotton (Anderson).

The trend in U.S. cotton production has been to lower costs, increase yield and expand acreage through the use of genetically engineered seeds (e.g., Bt and herbicide-tolerant varieties). Lange estimates that at least 16 million bales of exports are necessary to keep the U.S. cotton infrastructure in place and profitable. The need to export two thirds of the U.S. crop could make fiber characteristics at least as important as insecticide resistance or herbicide tolerance and yield.

In a recent acreage survey, 47% of cotton growers surveyed reported fiber quality to be "very important" when selecting a variety to plant. About 25.5% indicated "fairly important," and another 25.5% thought it was a factor but not a deciding factor. Less than 2% said it was "not at all important," and

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The authors thank the Mississippi State University Extension Service, Mississippi Agricultural and Forestry Experiment Station, and U.S. Department of Agriculture–Agricultural Research Service for their support of this research and three anonymous reviewers for their valuable comments and suggestions.

none reported it to be "not very important" (Anonymous 2005). Because of the relative importance of quality in domestic and international markets (Anderson; Anonymous 2004; Cleveland; Kausik), producers must balance quality, yield, and cost of production considerations when making production decisions. Seed characteristics and their resulting production outcomes are a critical component in this decision process, and these decisions are likely to be influenced by factors such as farm size, labor availability, and their mechanization complement.

The overall objective of this study is to examine producers' preferences for cottonseed. Specifically, we examine the preferences for alternative cottonseed packages varying by different levels of the attributes seed price, seed type/variety, lint yield, and fiber quality. Of particular interest is whether the recent emphasis on fiber quality in world markets translates into producer choices for seed characteristics. This study allows a direct estimation of the relative importance of seed characteristics on producer seed choices. Additionally, the effect of farm characteristics such as size and labor availability on seed choice is also examined. Using an extension of the McDonald and Moffitt decomposition for the two-limit Tobit model, Fernandez-Cornejo, Daberkow, and McBride studied genetically engineered (Bt and herbicide-tolerant) corn and herbicide-tolerant soybean. Results of that study did not support the *a priori* hypothesis that the adoption of Bt and herbicide-tolerant corn was scale-neutral, although it supported the hypothesis that adoption of herbicide-tolerant technology for soybean was invariant to farm size (scale-neutral). This is in keeping with Rogers' observation that the effect of farm size on adoption is more responsive to farm size at the early stages of the diffusion of an innovation (the case of the herbicide-tolerant corn), and becomes less important as diffusion increases.[1]

Willingness to pay (WTP) for seed characteristics is examined by utilizing a choice-based conjoint (CBC) experiment. The CBC analysis is used because it enables the estimation of the marginal values (utilities derived from profit) of different attributes through simple mail surveys. The CBC approach has been used in a number of contexts and settings to examine respondent WTP for characteristics of a good or service (Beggs, Cardell, and Hausman; Hudson and Lusk; Lusk, Roosen, and Fox; Nalley et al.). The resulting marginal WTP values provide information about the relative importance of seed characteristics, which provides information to seed breeders and genetics companies about potential demand for these characteristics. Additionally, this approach also allows for a direct investigation of the effects of farm characteristics on the marginal WTP for different seed characteristics/technologies.

Methods

A random utility model is used to represent utility of profit for seed characteristics, where utility of profit is a function of the attributes consistent with Lancaster's hedonic theory. We assume that, revenue and other production costs being given, a producer derives profit utility from the attributes of a seed bundle, this relationship being donated by

$$(1)\qquad U = U(Price, Variety, Yield, Quality),$$

where *Price* is seed price per acre, *Variety* is seed type (conventional, herbicide-tolerant, stacked-gene), *Yield* is lint yield in pounds, and *Quality* is the fiber quality (low, medium, high). We assume $\partial U/\partial Price < 0$, meaning that increases in price decrease the utility of profit. Additionally, $\partial U/\partial Variety > 0$, or improvements in seed variety increase utility of profit.[2] Similarly, $\partial U/\partial Yield > 0$; that is, increases in yield increase producer utility of

[1] For a fuller discussion and illustration on the relationship between technology adoption and scale, see, for example, El-Osta and Johnson; El-Osta and Morehart; Kinnucan et al.; and Kuchler and Offutt.

[2] Because the seed variety represents production technologies and therefore has no effect on output price, we are inherently assuming here that increasing technology levels are associated with lower costs of production.

Table 1. Attributes and Attribute Levels Used in Choice-Based Conjoint Experiment

	Attribute Level		
Attribute	1	2	3
Seed price (per acre)[a]	$16	$34	$75
Seed type/variety[b]	Conventional	Herbicide-tolerant[c]	Stacked-gene[d]
Lint yield (pounds per acre)[e]	750	1,000	1,500
Fiber quality[f]	Low[g]	Medium[h]	High[i]

[a] The buying price of cottonseed (i.e., the cost producers incurred or were willing to incur to buy cottonseed).
[b] The type of cottonseed producers had the choice to buy.
[c] The herbicide-tolerant type of cottonseed allows the farmer to use postemergent herbicides. For example, glyphosate is an herbicide effective on many species of grasses, broadleaf weeds, and sedges.
[d] The stacked-gene type of cottonseed combines the properties of both insect resistance (e.g., Bt) and herbicide tolerance.
[e] The lint yield producers could expect from their cotton farming operation.
[f] The quality of cotton fiber producers could expect.
[g] Producers were assumed to receive a discount of 0 to 2 cents per pound of lint for this quality of cotton fiber.
[h] Producers were assumed to receive a premium of 0 to 2 cents per pound of lint for this quality of cotton fiber.
[i] Producers were assumed to receive a premium of 3 to 5 cents per pound of lint for this quality of cotton fiber.

profit. Finally, $\partial U/\partial Quality > 0$ means that improvements in fiber quality increase producer utility of profit, generally through a higher output price. By assuming that the attributes of seed can be treated separably from other inputs, it is assumed these attributes are weakly separable from other inputs.

CBC Analysis

The theoretical model was operationalized by the use of CBC analysis, or choice experiment, to determine the effects of seed attributes on producer profit utility. A mail survey of cotton producers in Mississippi was conducted in February and March 2005. To determine the relative importance placed by producers on the attributes of price, seed type, lint yield, and fiber quality of cottonseed, each producer was presented with discrete choices between two packages and a choice of neither package (or "opt out" or "do not buy"). Each attribute was varied by three different levels (Table 1). The decision to choose a certain package could be viewed as a choice of a bundle of attributes, each of which provides subjective utility from profit to the producer (Lancaster). This method is relatively easy to administer compared with the alternative of personal interview and does not limit sample size (Ayidiya and McClendon; Hudson and Lusk; McFarlane and Garland).[3]

The CBC method is often used in transportation, environmental, marketing, and other business literature to estimate the utility of product attributes ("product" being broadly defined) or predict consumer choice by determining the relative importance of various attributes in consumers' choice process (Adamowicz et al. 1997, 1998; Beggs, Cardell, and Hausman; Hudson and Lusk; Jayne et al.; Lusk, Roosen, and Fox; Mark, Lusk, and Daniel; Roe, Boyle, and Tiesl; Unterschultz et al.; Wardman). The CBC analysis has been known to effectively predict the success of new products (Jayne et al.), genetically modified products (Lusk, Roosen, and Fox; Lusk et al.), and quality-differentiated products (Loureiro and Hine; Lusk and Schroeder; Nalley et al.). It has been shown to be consistent with consumers' revealed preferences (Adamowicz, Louviere, and Williams; Adamowicz et al. 1997) and robust to hypothetical bias (Carlsson and Martinsson; Hudson, Gallardo, and Hanson). The CBC method is also appealing in that it is based on random utility theory (Louviere, Hensher, and Swait), allows for

[3] It should be noted that the 117 participants in this survey generated 4,488 observations on choice.

multiattribute valuation (Hudson and Lusk), and permits the measurement of trade-offs among numerous attributes (Lusk, Roosen, and Fox). Although the use of the CBC method is limited on producer preferences to cater to the interest of agribusinesses such as seed companies, technology and equipment dealers, and agricultural service providers, it has occasionally been used to elicit producer (farmer) WTP for a new product or service (Hudson and Hite; Lusk and Hudson).

Experimental Survey Design

The CBC technique provides the inherent advantage of allowing deliberate manipulation of attributes across choice sets to test specific hypotheses. However, administering an experiment with the full factorial design of all possible combinations of attribute levels is cumbersome and expensive (Hudson and Lusk). On the basis of the number of attributes and attribute levels, a full factorial design would consist of $3^4 = 81$ possible scenarios. It was unrealistic to expect that each individual would examine all 81 different choice sets.[4] To restrict this number, a fractional factorial design was created that maximized design efficiency (minimized attribute correlation) while maintaining design orthogonality (Kuhfeld, Tobias, and Garratt).[5] A total of 26 scenarios were created by this process. To minimize respondent fatigue and increase response rates, the scenarios were randomly divided into two blocks of 13 scenarios,[6] each scenario containing two alternative choice packages (A and B) of specified levels of each attribute with the option of choosing none of the two choice packages (Choice C, "Neither," meaning "Don't Buy Either Package A or Package B").

A questionnaire consisting of the 13 scenarios as well as demographic questions was sent to each of the 600 cotton producers (300 receiving each block) selected randomly by a simple MS-Excel random number generator from a possible list of 1,319 cotton producers in the Mississippi Delta region provided by county extension offices. Following Dillman's general mail survey procedures, the questionnaire was sent along with a postage-paid return envelope and a cover letter explaining the purpose of the survey. A follow-up mailing was sent to producers not responding to the initial mailing approximately 3 weeks later.

Out of the 600 questionnaires mailed, three were returned undeliverable. Of the 203 questionnaires that were returned, 86 were unusable with, 83 indicating the respondents were no longer cotton producers, and three were returned blank. Therefore, a total of 117 cotton producers' responses (questionnaires) were usable. Of these 117 respondents, 41% were from the first block and 59% from the second. Assuming nonrespondents to the survey were active cotton producers, overall response rate was approximately 34% (203/597), and the usable response rate was approximately 22.8% (117/514). Although somewhat lower than desired, this rate was within the acceptable norm for mail surveys

[4] In designing an experiment, it is often necessary to make a trade-off between statistical efficiency and the number of possible choice sets administered. Although a larger design has better statistical efficiency and larger burden on the respondent or in administering, a smaller design is clearly advantageous for visual inspection and investigation of the choice sets "for poorly matched attribute options" (Lusk and Norwood, p. 774). Obviously, the latter is a task that becomes increasingly difficult with the growth in size of the design.

[5] Lusk and Norwood, AJAE, Aug 2005, showed that the approach on CBC experimental design followed by Kuhfeld, Tobias, and Garratt performs as well at identifying the underlying utility function as any other experimental design.

[6] In experimental design, researchers must be concerned with the "effects" that they are attempting to estimate (Louviere, Hensher, and Swait). A simple model attempts to estimate the main effects, whereas more complex models incorporate two-way and higher order interactions between the attributes. The more interaction effects are incorporated, the more complex and sizable the experimental design becomes. An experimental design that only incorporates main effects is unusable to estimate two-way and higher order interaction effects. In this analysis, we incorporated main effects only. Thus, the models presented are all without interaction effects.

(Dillman), and the demographic characteristics well represented the region (Table 3).

Producers who grew cotton in 2004 or planned to grow it in 2005 were presented with a set of attributes: seed price, seed type (variety), lint yield, fiber quality, and other considerations. With the use of a Likert scale ranging from 1 (very important) to 5 (very unimportant), producers were asked to evaluate how each of these attributes would influence their decision when purchasing cottonseed.

The choice variables were defined, with seed price (per acre) referring to the buying price of cottonseed (i.e., the cost producers incurred or were willing to incur to buy cottonseed). The three price levels presented were \$16, \$34, and \$75 per acre.[7] Seed type referred to the type (or variety) of cottonseed producers could buy. Three different types were included: conventional, herbicide-tolerant, and stacked-gene (i.e., herbicide-tolerant as well as insect-resistant). The design allowed each of these types to assume any of the three price levels specified, thus not constraining conventional seed to always be the least expensive seed and stacked-gene the most expensive seed.[8] Lint yield (pounds per acre) referred to the lint yield producers could expect from the seed presented in the scenario, which were representative of typical "low" (750 lb), "average" (1,000 lb), and "high" (1,500 lb) yields for the Delta region. Fiber quality referred to the quality of fiber producers could expect. Three different standards were assumed in this study: Low, Average, and High. For Low quality, profits were lowered by a discount of 0 to 2 cents per pound of lint; a premium of 0 to 2 cents per pound of lint would be received for Average quality, and High quality would receive a premium of 3 to 5 cents per pound of lint. The different attributes and attribute levels used in this study are shown in Table 1.

Each of the 13 scenarios was presented in the form of a table, with the names of the attributes (choice variables) on the first column and the attribute levels of price, seed type, lint yield, and fiber quality stated on the two subsequent columns. Each column defined a choice package (A or B), with a certain level each of seed price, seed type, lint yield, and fiber quality. These levels were varied across scenarios and within the two blocks in accordance with the derived fractional factorial design. The fourth column had the heading "Neither," giving the respondent the option to choose neither Package A nor Package B. An example scenario is shown in Figure 1.

Scenario 1. Packages A and B represent two different descriptions for a purchasing arrangement. Please check (✓) the package (A, B, or Neither) that you would be most likely to choose.

Attribute	Package A	Package B	Neither
Seed Price (per acre)	\$16	\$75	
Seed Type	Conventional	Stacked–Gene	
Lint Yield (pounds per acre)	1,000	1,500	
Fiber Quality	High	High	
I would choose . . .	☐	☐	☐

Survey mailed to cotton producers in the Mississippi Delta

Figure 1. Example Choice Set Used in Conjoint Experiment.

[7] These prices were derived with the use of normal seeding rates for the Mississippi Delta. Although some producers might seed at greater or lesser rates than commonly prescribed, these prices encompassed typical per-acre seed charges in this area.

[8] Although constraining seed prices so that conventional seed was always the least expensive might seem to make intuitive sense, it would fracture the factorial design, thus introducing unknown correlations of attributes. Furthermore, Monte Carlo simulation results have shown that forcing these naturally correlated attributes (in this case, seed type and price) is not necessary to generate reliable results. On the contrary, forcing that correlation can actually increase error rates substantially. See Moore and Holbrook for further discussion.

Modeling Approaches and Estimation

Approach 1: Conditional Logit Model

Following Louviere, Hensher, and Swait, a random utility model is defined as

$$(2)\quad U_{ij} = V_{ij} + \varepsilon_{ij},$$

where U_{ij} is the i^{th} producer's subjective utility of profit for seed bundle j under the maintained hypothesis that this seed bundle will affect profitability, V_{ij} is the deterministic portion of this utility of profit (to be maximized) and ε_{ij} is the stochastic component. The probability of choosing any of these j seed bundles is

$$(3)\quad \begin{aligned} &\Pr\{j \text{ is chosen}\} \\ &\quad = \Pr\{V_{ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik} \text{ for all } k \in C_i\}, \end{aligned}$$

where C_i is the choice set for producer i ($C_i = \{A, B, C\}$), Choice C = "Neither" in Figure 1, and

$$(4)\quad \begin{aligned} V_{ij} = {} & \beta_0 + \beta_1 Price_{ij} + \beta_2 Herbicide \\ & \text{-}Tolerant_{ij} + \beta_3 Stacked\text{-}Gene_{ij} \\ & + \beta_4 Yield_{ij} + \beta_5 MediumQuality_{ij} \\ & + \beta_6 HighQuality_{ij} + \varepsilon'_{ij} \end{aligned}$$

is the indirect utility-of-profit function of option j for respondent (producer) i to be estimated. The explanatory variables are described in Table 1, and β_0 through β_6 are the parameters to be estimated. In particular, β_0 is an alternative-specific constant (ASC), also known as a location parameter, associated with option j for respondent (producer) i.

Assuming the random errors in Equation (1) are independently and identically distributed across the j alternatives and N individuals, and have a Type I extreme value distribution and scale parameter equal to 1, Ben-Akiva and Lerman have shown the probability of producer i choosing choice j is given by

$$(5)\quad \Pr\{j \text{ is chosen}\} = \frac{e^{\mu V_{ij}}}{\sum_{k \in C} e^{\mu V_{ik}}},$$

where μ is the scale parameter, assumed equal to 1, because it is unidentifiable within any particular data set (Lusk, Roosen, and Fox). A conditional logit (CL) model constituting the attribute levels reported in Table 1 was estimated with Equation (5). *Price* and *Yield* were entered into the equation as continuous variables. Variety entered the equation as two dummy variables—*Herbicide-Tolerant* and *Stacked-Gene*—with *Conventional* serving as the base. Quality entered the equation as two dummy variables—*MediumQuality* and *HighQuality*—with *LowQuality* serving as the base.

The estimated coefficients in Equation (5) represent the marginal utilities of the relevant attributes. When the ratio of a particular marginal utility of an attribute is taken relative to the marginal utility of money (the price coefficient), this yields the marginal rate of substitution of money for the attribute, or the marginal WTP. The values producers place on the different attributes represent the profit increase (decrease) needed to offset the positive (negative) utility provided by a particular attribute. For example, assume that producers received positive marginal utility of profit from both yield and fiber quality. These assumptions suggest that the producer is willing to forgo some yield to obtain better fiber quality. By examining the ratio of the parameter estimate for fiber quality relative to the parameter estimate of profit (the ratio of marginal utilities of profit), an estimate of the amount of money the producer is willing to forgo to obtain better fiber quality is obtained (Hudson and Lusk). This has been discussed further in the WTP Estimates subsection after the discussion of Approach 2.

Approach 2: Random Parameters Logit Model

The CL model above is limited primarily in two ways. First, the model outlined assumes all respondents share the same coefficients for all relevant attributes, meaning they are assumed to have the same preferences for cotton attributes. Such homogeneity in preferences is likely unrealistic. In many cases, one might expect heterogeneity in preferences within the population. Second, because farm or other respondent characteristics are fixed across all choices for each respondent, they are perfectly collinear with the intercept and must be dropped. This result prevents analysis of the effects of these characteristics on choice.

A mixed or random parameters logit (RPL) model is often used to investigate heterogeneity of preferences (Layton and Brown; Revelt and Train; Train). In the RPL model, the βs from Equation (5) are allowed to vary across the population with an assumed (in this case, normal) distribution. In general, individual i will have a coefficient vector given by $\beta_i = \bar{\beta} + \sigma \mathbf{u}_i$, where $\bar{\beta}$ is the population mean, σ is a diagonal matrix of coefficient standard deviations, and $\mathbf{u}$ is a vector of independent standard normal deviates. This specification assumes the coefficients vary randomly over individuals to capture the potential variation in tastes for specific cottonseed attributes and relaxes the restriction that every respondent exhibits constant marginal utilities of profit for choice attributes. Although the parameters are allowed to vary across the population, the individual characteristics can then be used to examine systematic elements of the preference heterogeneity.

The advantage of the RPL method is that it is not subject to the independence from irrelevant alternatives assumption found in the CL model and accounts for the repeated observations taken from each respondent (Layton and Brown; Revelt and Train; Train). The results of this model provide an indication of the variability of seed characteristic preferences within the sample. Additionally, individual-specific (farm) characteristics can then be used to explain any observed heterogeneity in preferences, which affords a direct analysis of farm characteristics on preferences.

The price coefficient is assumed fixed in the population. The same data from modeling approach 1 were used to estimate the RPL in modeling approach 2. Louviere, Hensher, and Swait contend that, if respondents are relatively homogeneous in their preferences (as in this case for cottonseed attributes), modeling approaches 1 and 2 should be equivalent (Lusk, Roosen, and Fox).

WTP Estimates

Point estimates of WTP are obtained in both the above modeling approaches by the simple formula:

$$(6) \quad WTP_j = \left|\frac{\beta_j}{\beta_1}\right|,$$

where β_j is the response coefficient for the j^{th} attribute, and β_1 is the estimated coefficient for price, holding all other potential influences constant (Louviere, Hensher, and Swait, p. 61). Krinsky and Robb proposed bootstrapping confidence intervals around the WTP estimates to facilitate statistical tests. The variance–covariance matrix produced during the estimation process was thus used to generate a bivariate normal density on WTP_j with 1,000 simulated observations, and a 95% confidence interval on $\overline{WTP_j}$ was constructed from these simulated observations.

Results

Assuming a cotton producer derives utility from profit and the decision to purchase cottonseed depends on the attributes of seed price, seed type, lint yield, fiber quality, and other considerations, the survey asked the respondents to evaluate on a scale of 1 to 5 how each of these attributes would influence their decision when purchasing cottonseed. Based on the responses received, "other considerations" had the highest mean of 2.53. Seed price was second, with a mean of 2.28. The means of fiber quality, seed type, and lint yield were, respectively, 1.82, 1.68, and 1.60. These results, along with their standard deviations, are shown in Table 2.

The means and standard deviations of age, farm labor, education, and income are presented in Table 3. These demographic variables were similar to those in the 2002 Census of Agriculture for the Delta region of Mississippi (USDA 2006b) and a 2005 survey of Mississippi cotton producers (Banerjee and Martin).

From the regression results of the CL model (Table 4), both of the constants (ASC1 and ASC2) associated with the pack-

Table 2. Summary Statistics on Factors (Seed Price, Seed Type, Lint Yield, Fiber Quality, Other Considerations) Assumed to Influence Cotton Producers' Decision in Purchasing Cottonseed, as per Mail Survey in the Mississippi Delta, 2005[a]

Procedure	Seed Price	Seed Type	Lint Yield	Fiber Quality	Other
Mean	2.28	1.68	1.60	1.82	2.53
SD	1.27	1.25	1.32	1.22	1.12

[a] Producers were asked to evaluate each factor from 1 (very important) to 5 (very unimportant). Therefore, the numbers in the row for mean in the table indicate the relative importance of the respective factors.

Table 3. Summary Statistics on Age and Education of Cotton Producers, and Farm Labor and Revenue of Cotton-Producing Households, as per Mail Survey in the Mississippi Delta, 2005

Procedure	Age	Farm Labor	Education	Revenue	Acres
Mean[a]	52.86[b]	4.82[c]	2.58[d]	2.56[e]	1,630.88[f]
SD	12.19	4.39	0.80	0.62	2,122.11

[a] For all farmers with 2,000 or more acres, the 2002 Census of Agriculture for Mississippi reports average age of 54.9 years, average number of hired farm laborers 8.36 (7,092 workers on 848 farms with hired labor), and net annual farm revenue of $148,000. Forty-six percent of the respondents to a 2005 precision farming survey of cotton producers indicated they had a college degree (BS/BA), and 93% of them at least had a high school degree (Banerjee and Martin).

[b] Average age of respondent (cotton producer) in years.

[c] Average number of laborers, including respondent, engaged in farming operation.

[d] Highest level of education attained by the respondent (cotton producer) on average: 1, high school; 2, some college; 3, college graduate; 4, graduate or professional degree.

[e] Average annual household revenue of respondent (cotton producer) from farming: 1, <$50,000; 2, $50,000–$250,000; 3, >$250,000.

[f] Average acres of cotton planted in 2004. Reported cotton acreage ranged between 0 and 11,000 acres. This range was consistent with the 2002 U.S. Agricultural Census data, which revealed that 68% of the Mississippi cotton acreage was on farms of 1,000 acres or more.

age choices A and B, respectively, appear to have negative signs, indicating that, on average, respondents preferred "Neither" (Choice C) to either of the two packages A and B. The coefficient on price is negative, as expected: increase in price of cottonseed lowers the probability of purchase. The positive signs and statistical significance on technology coeffi-

Table 4. Conditional Logit Model Regression Results

Variable	Coefficient	SE	t-Ratio[a]
ASC1	−5.5035	0.3255	−16.91
ASC2	−5.2403	0.3199	−16.38
Price	−0.0224	0.0020	−11.02
Herbicide-Tolerant	1.4835	0.1341	11.06
Stacked-Gene	1.9417	0.1338	14.52
Yield	0.0044	0.0002	20.45
MediumQuality	0.8538	0.1249	6.83
HighQuality	1.3903	0.1339	10.38
Log likelihood	−1,068.49		
R^2	0.3499		
Number of observations	4,488		

Note: *ASC1* and *ASC2* are alternative-specific constants.

[a] All the t-ratios indicate statistical significance at the 0.01 level.

Table 5. Marginal Willingness to Pay (*WTP*, $) from Conditional Logit Model

Variable	*WTP*
Herbicide-Tolerant	66.11
	[53.30, 81.76][a]
Stacked-Gene	86.71
	[76.28, 97.36][a]
Yield	0.20
	[0.17, 0.23][a]
MediumQuality	38.08
	[28.02, 49.83][a]
HighQuality	62.11
	[52.15, 72.16][a]

Notes: Herbicide-tolerant and stacked-gene figures are relative to the conventional variety. Medium and high qualities are relative to low-quality cotton. Yield is on a per-pound basis.

[a] The figures in brackets indicate 95% confidence levels for the relevant variables.

cients (herbicide-tolerant and stacked-gene varieties) and fiber quality (both medium and high) indicate the importance of these attributes to respondents. All coefficients here are positive, implying that these attributes increase utility of profit (have a positive marginal utility) to the producer. All *t*-ratios are significant at the 1% level of significance.

Utilizing the variance–covariance matrix produced during the WTP estimation process, the Krinsky–Robb procedure was used to bootstrap 95% confidence intervals around the WTP estimates, as shown in Table 5. The marginal WTP estimates from the CL also imply producer demand for the relevant attributes. The marginal WTP for the herbicide-tolerant seed versus the conventional variety is $66.11 per acre. Even though herbicide-tolerant cottonseed in the study area was less expensive in 2004 and 2005 ($26 and $31 per acre, respectively), this could indicate the true WTP when factors such as convenience, protection from herbicide drift, and unwillingness to go back to the "conventional" ways of farming are considered. The marginal WTP for stacked-gene seed versus conventional seed is $86.71. Because stacked-gene seed combines the properties of insecticide resistance along with herbicide tolerance, the marginal WTP for the stacked-gene variety is expected to be higher than the herbicide-tolerant variety. Combining the results from these two varieties could provide more insight because, in order to get the "package" (yield, insect resistance, and herbicide tolerance), producers often must buy the stacked-gene seed. Thus, there is a compound effect of the stacked-gene variety relative to just the herbicide-tolerant variety. If the cost of the Bt seed technology expense/fee ($32.00) is subtracted from $86.71, the herbicide tolerance portion ($86.71 – $32.00 = $54.71) becomes even less expensive than the WTP estimate ($66.11). Therefore, there is a positive marginal WTP for technology relative to conventional cottonseed, and this WTP increases with the level of technology.

The marginal WTP for lint yield is approximately $0.20 per pound. Given the cotton loan price of $0.52 per pound, production cost beyond the seed must be $0.32 per pound or less to induce the producer to pay $0.20 for each pound of additional yield. The marginal WTP for medium and high fiber qualities are approximately $38.08 and $62.11 per acre, respectively.[9] Thus, there is a positive marginal WTP for yield and quality.

To account for potential heterogeneity, an RPL model was estimated. The results obtained from this model are shown in Table 6. The constant terms (ASCs) and variety dummies in this model were allowed to vary randomly in the population. In the model, the heterogeneity of these parameters was a function of farm labor and farm acres. The choice of random parameters was arbitrary, and these were selected to observe changes in only technology with respect to the stated variables (farm labor and acres). Holding other parameters constant allows examination of heterogeneity with respect to biotechnology. Price was also held constant to allow calculation of *WTP*. The overall effects of the RPL model are similar to those observed in the CL model, with all estimated parameter coefficients

[9] Interestingly, assuming a 1,000 lb/acre yield, these marginal WTP values are approximately $0.04/lb and $0.06/lb, respectively, which are close to the stated anticipated premiums for these qualities.

Table 6. Random Parameters Logit Model Regression Results

Variable	Coefficient[a]	SE	*t*-Ratio
	Random Parameters in Utility-of-Profit Function		
ASC1	−5.4459	0.3850	−14.146***
ASC2	−5.2120	0.3850	−13.541***
Herbicide-Tolerant	1.5515	0.2244	6.913***
Stacked-Gene	1.7720	0.2054	8.627***
	Nonrandom Parameters in Utility-of-Profit Function		
Price	−0.0227	0.0021	−10.638***
Yield	0.0045	0.0002	19.297***
MediumQuality	0.9204	0.1333	6.906***
HighQuality	1.4326	0.1558	9.194***
	Heterogeneity in the Mean, Parameter:Variable		
ASC1:Farm Labor	0.0181	0.0275	0.661
ASC1:Acres	−0.0002	0.0001	−2.717***
ASC2:Farm Labor	0.0316	0.0246	1.286*
ASC2:Acres	−0.0002	0.0001	−3.139***
Herbicide-Tolerant:Farm Labor	−0.0603	0.0316	−1.911**
Herbicide-Tolerant:Acres	0.0002	0.0001	2.104**
Stacked-Gene:Farm Labor	−0.0558	0.028	−1.991**
Stacked-Gene:Acres	0.0003	0.0001	3.456***
Log likelihood	−1,116.56		
R^2	0.3551		
Number of observations	4,488		

Notes: *ASC1* and *ASC2* are alternative-specific constants. Heterogeneity of the mean refers to changes in the mean parameter value because of changes in the stated variable (farm labor or acres).

[a] Reported coefficient estimates are mean estimated values of varying parameters.

* Significant at the 0.1 level.

** Significant at the 0.05 level.

*** Significant at the 0.01 level.

having the same expected sign and statistical significance.

Each of the signs on the heterogeneity estimated parameters shows how the relevant estimated preference parameter changes as the variable (farm labor or acres) changes. For example, the parameter *Herbicide-Tolerant*: Farm Labor is negative (−0.0603). Thus, this parameter adjusts the "mean" of the herbicide-tolerant parameter downward with increases in farm labor. The "mean" of the herbicide-tolerant marginal utility of profit decreases as farm labor increases, implying a lower marginal WTP for herbicide-tolerant technology with more available farm labor. In fact, for each additional farm laborer, the average WTP for herbicide-tolerant seed decreases by $2.66/acre.[10] Thus, farm labor and herbicide-tolerant biotechnology are substitute inputs. Similarly, the parameter *Stacked-Gene*:Farm Labor is negative (−0.0558). Thus, as farm labor increases by one unit, the mean WTP for stacked-gene technology decreases by $2.46/acre. This result further reinforces the conclusion that biotechnology and farm labor are substitute inputs in cotton in the Mississippi Delta, similar to the macroeconomic effect of high-

[10] This value is determined by taking the value of the *Herbicide-Tolerant*:Farm Labor coefficient from Table 6 divided by the coefficient for price. The result is a change in marginal WTP with respect to changes in farm labor.

yielding varieties of food grains under the Green Revolution in India in the 1960s.

The parameters *Herbicide-Tolerant*:Acres and *Stacked-Gene*:Acres are positive (0.0002 and 0.0003, respectively). Thus, each of these heterogeneity parameters enhances the "mean" of the herbicide-tolerant and stacked-gene parameters, respectively, and so enhances the WTP for biotechnology. From the producer's perspective, then, there are economies of size in biotechnology adoption so that biotechnology is not size-neutral, which supports Fernandez-Cornejo, Daberkow, and McBride's study on Bt and herbicide-tolerant corn.

Conclusions

This analysis used the choice-based conjoint technique to examine preferences for four choice attributes of cottonseed: price, yield, variety, and fiber quality. Mail surveys of agricultural producers in Mississippi were conducted to gather choice information. Random utility models were estimated, and estimates of the monetary value of attributes were derived from these marginal utility of profit estimates.

The marginal WTP approach with the use of a CL model revealed WTP for herbicide-tolerant varieties of cottonseed relative to the conventional variety as $66.11 per acre, and WTP for stacked-gene (also relative to the conventional variety) as $86.71 per acre. Thus, technology had a positive WTP relative to the conventional variety of cottonseed, and WTP increased with the level of technology. The WTP for yield was positive, and approximately $0.20 per pound. Fiber quality also had a positive WTP, which increased as quality increased—$38.08 for medium and $62.11 for high—relative to the base (low) quality.

From the RPL model, the heterogeneity of farm characteristics was examined. Preferences for cottonseed attributes exhibited significant heterogeneity within the population. While not surprising, these results indicate that this heterogeneity could have profound effects on the efficacy of agricultural policy design. Larger farms had a higher WTP for technology than smaller farms, and farms with more farm labor had a lower WTP for technology. Indirectly, these results provide evidence that, whereas on the one hand, adoption of cost-saving biotechnology provide economies of size, farm labor and genetic modification are substitute inputs in cotton production. Whether declines in farm labor availability are driving technology adoption or whether increases in technology adoption are leading to declines in farm labor demand is not determined here, but it is clear that these two inputs serve as direct substitutes. This result has implications for rural policy in that increased adoption of biotechnology in the farm sector is likely to be associated with decreases in farm labor demand.

[Received August 2006; Accepted November 2006.]

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