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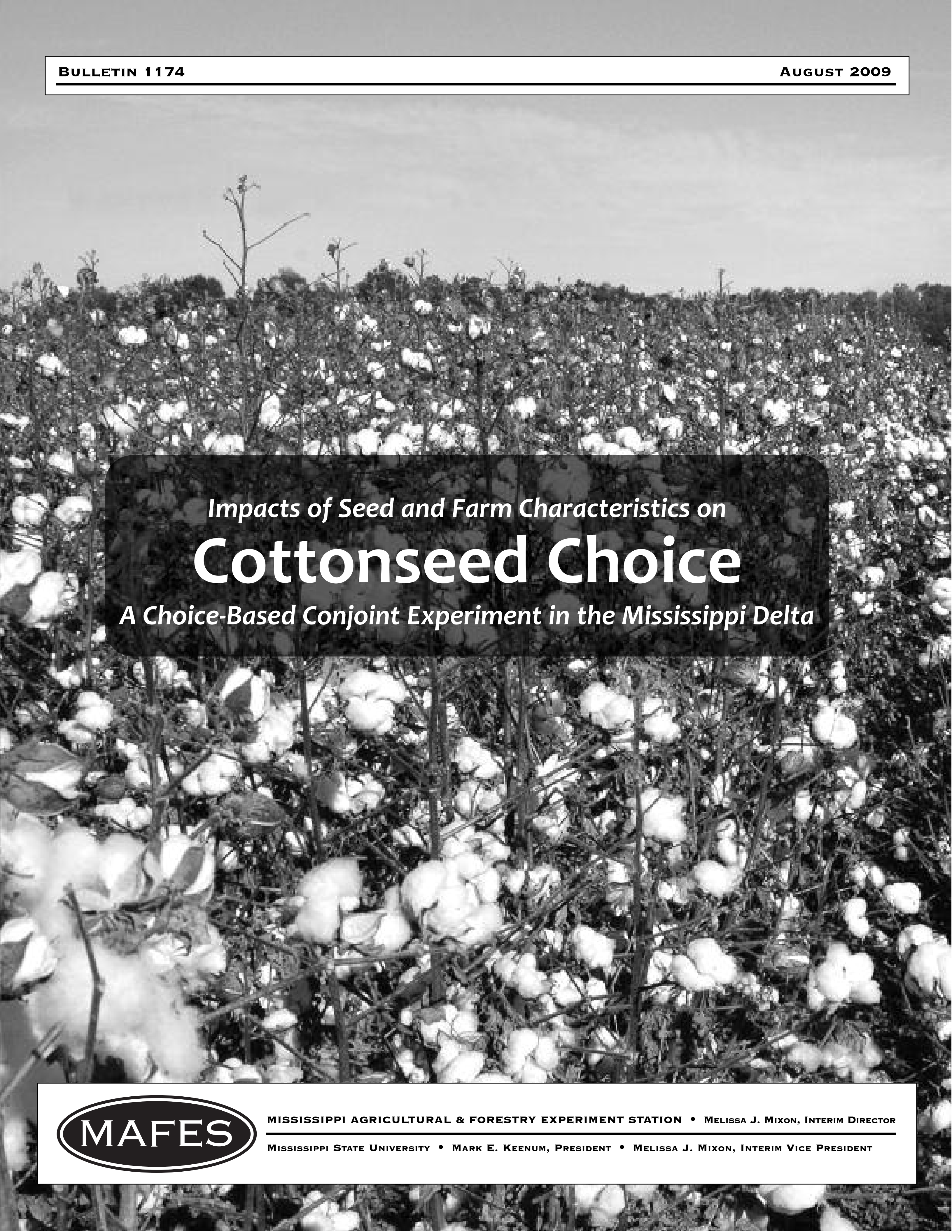

Impacts of Seed and Farm Characteristics on

Cottonseed Choice

A Choice-Based Conjoint Experiment in the Mississippi Delta

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Impacts of Seed and Farm Characteristics on Cottonseed Choice:

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Abstract

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

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INTRODUCTION

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 the U.S. cotton is now marketed in the world export market. Thus, U.S. producers must strive to produce 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 in order to keep U.S. cotton infrastructure in place and profitable. The need to export two-thirds of the U.S. crop may 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 none reported it to be "not very important" (*Cotton Grower*). Because of the relative importance of quality in domestic and international markets (Anderson; Cleveland; *Cotton Grower Plus*; 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 was to examine producers' preferences for cottonseed. Specifically, we examined the preferences for alternative cottonseed packages varied by different levels of the attributes of seed price, seed type/variety, lint yield, and fiber quality. Of particular interest was whether the emphasis on fiber quality in world markets translated into producer choices for seed characteristics. This study allowed a direct estimation of the relative importance of seed characteristics on producer seed choices. Additionally, the impact of farm characteristics such as size and labor availability on seed choice was 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 soybeans. Results of that study did not support the *a priori* hypothesis that the adoption of Bt and herbicide-tolerant corn was scale-neutral, though it supported the hypothesis that adoption of herbicide-tolerant technology for soybeans was invariant to farm size (scale-neutral). This supported Rogers' observation that the impact 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.

Willingness to pay (WTP) for seed characteristics was examined by utilizing a choice-based conjoint (CBC) experiment. The CBC analysis was used because it enabled 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 impacts of farm characteristics on the marginal WTP for different seed characteristics/technologies.

METHODS

A random utility model was used to represent utility of profit for seed characteristics, where utility of profit was a function of the attributes consistent with Lancaster's hedonic theory. We assumed that, revenue and other production costs being given, a producer can derive profit utility from the attributes of a seed bundle, which were denoted by:

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

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

Choice-Based Conjoint (CBC) Analysis

The theoretical model was operationalized by using the choice-based conjoint (CBC) analysis, or choice experiment, to determine impacts of seed attributes on producer profit utility. A mail survey of cotton producers in Mississippi was conducted in February and March of 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 may be viewed as a choice of a bun-

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

Attribute	Attribute Levels		
	Level 1	Level 2	Level 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 0–2 cents per pound of lint for this quality of cotton fiber.
[h]Producers were assumed to receive a premium of 0–2 cents per pound of lint for this quality of cotton fiber.
[i]Producers were assumed to receive a premium of 3–5 cents per pound of lint for this quality of cotton fiber.

dle 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 (Hudson and Lusk; McFarlane and Garland; Ayidiya and McClendon).

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). Based on the number of attributes and attribute levels, a full factorial design would consist of $3^4 = 81$ possible scenarios. It was unrealistic to expect each individual to examine all 81 different choice sets. 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). A total of 26 scenarios were created using this process. To minimize respondent fatigue and increase response rates, the scenarios were randomly divided into two blocks of 13 scenarios, each scenario containing two alternative choice packages (A and B) of specified levels of each attribute, and 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, along with 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 who did not respond 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; 83 of these indicated 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% were 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 22.9% (117/511). While somewhat lower than desired, this rate was within the acceptable norm for mail surveys (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. Using a 1–5 Likert scale (1 = very important, 5 = very unimportant), we asked pro-

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 . . .	☐	☐	☐

Figure 1. Example Choice Set Used in Conjoint Experiment (Source: Survey mailed to cotton producers in the Mississippi Delta).

ducers 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). Three price levels presented were \$16, \$34, and \$75 per acre. 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. 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 pounds), "average" (1,000 pounds), and "high" (1,500 pounds) yields for the Delta region. Fiber quality referred to the quality of fiber that producers could expect. Three different standards were assumed in this study: low, average, and high quality. For low quality, profits were lowered by a discount of 0–2 cents per pound of lint. Average quality would earn a premium of 0–2 cents per pound. High quality would earn a premium of 3–5 cents per pound. 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, followed by 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.

Modeling and Estimation

Conditional Logit (CL) Model

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

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

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) $\Pr\{j\ is\ chosen\} = \Pr\{V_{ij\,ij} + \varepsilon_{ij} \geq V_{ik} + \varepsilon_{ik};\ for\ all\ k \in C_i$

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

(4) $V_{ij} = \beta_0 + \beta_1 Price_{ij} + \beta_2 Herbicide\text{-}Tolerant_{ij} + \beta_3 Stacked\text{-}Gene_{ij} + \beta_4 Yield_{ij} + \beta_5 Medium\ Quality_{ij} + \beta_6 High\ Quality_{ij} + \varepsilon_{ij}$

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 "location parameter," associated with option j for respondent (producer) i.

Assuming the random errors in Equation (1) are independently and identically distributed (iid) 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) $\Pr\{j\ is\ chosen\} = \dfrac{e^{\mu V_{ij}}}{\sum_{k \in C} e^{\mu V_{ik}}}$

where μ is the scale parameter, assumed equal to one, 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 — Medium Quality and High Quality — with Low Quality 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 forego 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 forego to obtain better fiber quality is obtained (Hudson and Lusk).

Willingness-to-Pay (WTP) Estimates

Point estimates of willingness to pay (WTP) are obtained by:

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

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 utilized to generate a bivariate normal density on WTP_j using 1,000 simulated observations, and a 95% confidence interval on 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 1–5 how each of these attributes would influence their decision when purchasing cottonseed. Based on the responses received, “other considerations” had the highest mean (2.53). Seed price had the next highest mean (2.28), followed by fiber quality (1.82), seed type (1.68), and lint yield (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 conditional logit (CL) model (Table 4), both the constants (ASC1 and ASC2) associated with the package 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 coefficients (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 conditional logit also imply producer demand for the relevant attributes.

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
Std. Dev.[b]	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.
[b]Standard Deviation.

Table 3. Summary Statistics on Farm Labor, Household Revenue, and Cotton Producers' Age and Education from a 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]	1630.88[f]
Std. Dev.[g]	12.19	4.39	0.80	0.62	2122.11

[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, $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, 2006).
[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– Under $50,000, 2 – $50,000 to $250,000, 3 – Above $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 68% of the Mississippi cotton acreage was on farms of 1,000 or more acres.
[g]Standard Deviation.

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 may 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 combine the properties of insecticide resistance and 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 may 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 that cotton loan price is $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. Therefore, there is a positive marginal WTP for yield and quality.

Table 4. Conditional Logit Regression Results.

Variable	Coefficient	Standard Error	*t*-ratio[a]
ASC1	-5.5035	0.3255	-16.91
ASC2	-5.2403	0.3199	-16.38
Price	-0.0224	0.002	-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
Medium Quality	0.8538	0.1249	6.83
High Quality	1.3903	0.1339	10.38
Log-Likelihood	-1,068.49		
R-squared	0.3499		
Number of Observations	4,488		

[a]All the t-ratios indicate statistical significance at the 0.01 level. Note: ASC1 and ASC2 are alternative-specific constants.

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]
Medium Quality	$38.08 [28.02, 49.83][a]
High Quality	$62.11 [52.15, 72.16][a]

[a]The figures in brackets indicate 0.95 confidence intervals for the relevant variables. Notes: Herbicide-tolerant and stacked-gene figures are relative to “conventional” variety. Medium and high qualities are relative to “low” quality cotton. Yield is on a per-pound basis.

CONCLUSIONS

This analysis utilized 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. A random utility model was estimated, and estimates of the monetary value of attributes were derived from these marginal utility of profit estimates.

The marginal willingness-to-pay (WTP) approach using conditional logit revealed WTP for herbicide-tolerant variety 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. Therefore, there was a positive WTP for technology relative to the conventional variety of cottonseed, and WTP increased with the level of technology. The WTP for yield was positive — approximately \$0.20 per pound. There was also a positive WTP for fiber quality, which increased as quality increased — \$38.08 for medium and \$62.11 for high — relative to the base (low) quality.

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