Certainty Equivalent Farm Returns from Bt and Non-Bt Cotton

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Abstract

Annual mean returns and certainty equivalent returns for 1983-2003 were calculated for specified non-Bt cotton (refuge) percentages for a cotton farm of average size in the Mississippi Delta. Certainty equivalents indicate insecticide sprays influence mean profits more than the percentage of refuge in a cotton producer's portfolio. This supports an earlier study where returns calculated from both observed and simulated yields indicated, for any given refuge percentage, mean returns were higher with less risk when insecticides were sprayed compared to no sprays.

Keywords: Bt cotton, certainty equivalent, insecticide, refuge, returns, risk, simulated yield, spray.

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Introduction

Bt cotton is a genetically engineered variety of cotton named after a soil bacterium, *Bacillus thuringiensis* (Bt), whose genetically introduced toxins generally protects or provides high levels of suppression in cotton plants from certain lepidopteran insect pests including tobacco budworms, pink bollworms, cotton bollworms, armyworms, loopers, and other leaf- and fruit-feeding caterpillar pests in cotton. The U.S. Environmental Protection Agency (EPA), in pursuit of its interest in preserving the social welfare benefits and insect protection of the technology associated with Bt cotton, has mandated an Insect Resistance Management (IRM) program. According to that mandate, growers planting Bt cotton are required to follow the IRM practices designed so that some lepidopteran populations are not exposed to the Bt protein. This allows the reintroduction of susceptible pests into the selected populations, which delays pests' resistance. Thus, insects are provided a refuge food source that does not contain the Bt protein. This refuge is provided by farmers planting Bt cotton by simultaneously planting either 5 percent unsprayed or 20 percent sprayed non-Bt cotton as refuge. Comparison of the per-acre net returns from Bt and non-Bt cotton helps determine the importance of maintaining and managing this common natural resource of pest vulnerability.

Our primary objective in this analysis is to assess farmer welfare through the calculation of certainty equivalent returns. This extends an earlier study by Banerjee *et al.* (2005) comparing per-acre and total farm returns with various selected refuge requirements based on observed and simulated farm-level yields. Specifically, a cotton farm (average size 725 acres, USDA 2005) is studied in the Mississippi Delta, and simulated mean returns and certainty equivalent returns calculated for the period 1983 through 2003. Farm returns are shown in tables 1 and 2.

Data and Methods

Following Hurley *et al.* (2004), Banerjee *et al.* (2005) calculated per-acre returns and total farm returns for Bt and non-Bt cotton for the Mississippi Delta both with observed data (Cooke 2001) and simulated data (Coble *et al.* 2001; Miller *et al.* 2003). For both with and without insecticide spray applications (Regime 1 and Regime 2, respectively), for each of the refuge percentages of 0, 1, 5, 10, 20 and 26, one thousand iterations are performed for each year over the period 1983-2003, and mean returns for each scenario by year over that period obtained. The grand mean for each scenario is then calculated over the period 1983-2003.

Under constant relative risk aversion, the wealthier the farmer, the less risk averse he tends to be (Layard and Walters 1978). Certainty equivalents (CEs)[1] are often used as a measure of risk aversion. Under constant relative risk aversion, the grower's expected utility over wealth is

$$E(U_{sr}) = \sum_{t=1}^{m} \frac{W_{ts}^{1-r}}{m(1-r)}, \qquad r \neq 1,$$

or

$$E(U_{sr}) = \sum_{t=1}^{m} \frac{1}{m} \ln(W_{ts}), \qquad r = 1,$$

where U is utility, W is wealth at the end of each year, s is the scenario, t is the year, and r is the coefficient of constant relative risk aversion. The corresponding CE for each of the scenarios is denoted by

$$CE_{sr} = (1-r)E(U_{sr})^{1/(1-r)}, \qquad r \neq 1,$$

or

$$CE_{sr} = e^{E(U_{sr})}, \qquad r = 1.$$

Certainty equivalents for risk-aversion coefficients (RACs) of 1 and 2 were obtained using the above formulas, following Martin *et al.* (2001). The means are farmers' mean returns over 21 years (1983-2003), the mean for each year being obtained by averaging the results from the simulations.

Major Results and Implications

(1) CE as a proportion of mean are higher when insecticide sprays are applied compared to no insecticide sprays. This reinforces Banerjee *et al.*'s (2005) finding that whether or not sprays are applied is more important than percentage of non-Bt as refuge in the farmer's portfolio;

(2) As the percentage of refuge increases in a farmer's portfolio, CE as a proportion of mean decrease in greater amounts for the "no spray" regime than for the "spray regime"; and

(3) CE for RAC = 1 are consistently higher than CE for RAC = 2 for all scenarios, i.e., for any percentage of refuge.

Results are shown in tables 3 and 4.

One limitation of this current study is the lack of availability of farm yield data for any longer than four years. Farm yield data for 1983-2003 were simulated using data at the district (region) level from NASS and taking into account the deviations in yield between farm and region (Coble *et al.* 2001; Miller *et al.* 2003). Assuming constant relative risk aversion, a certainty equivalent (CE) mean value of returns for each scenario provided us with a more comprehensive picture of the comparison between returns from Bt and non-Bt cotton, with and

[1] A CE amount of return for a farmer is the amount he/she receives from a certain outcome when he/she is indifferent between the risky outcome and this certain outcome.

without insecticides. Our CE results reinforced our earlier claim that whether or not sprays were applied was more important than the relative proportion of non-Bt cotton used as refuge in the portfolio of a farmer.

Unlike past studies estimating the *ex post* value of Bt cotton to farmers, proving the benefit of these refuge requirements, the current study incorporated an *ex ante* expected value approach and was an attempt to show how planting Bt cotton affects farmer risk and welfare.

For future studies related to this area, assuming the farmer is optimizing profits, the farm-level marginal welfare effects of changing allocation arrangements between Bt and non-Bt cotton might provide additional insight. Additionally, a willingness-to-pay approach may be adopted to observe how farmers' willingness to pay would change in response to a 1 percent reduction (from both the 20 percent and 5 percent marks) in requirement to plant refuge cotton.

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Table 1 Total farm returns under various refuge scenarios in the Mississippi Delta, 1997-2000, without insecticide spray application(s): Regime 1[a]

z[b]	1997	1998	1999	2000	Mean	SD[c]	CV[d]
				($\tau = 0$)[e]			
0	$260,645	$229,908	$188,166	$177,313	$214,008	$38,480	0.180
1	$258,773	$227,838	$186,605	$175,661	$212,219	$38,314	0.181
5	$251,282	$219,554	$180,360	$169,054	$205,063	$37,652	0.184
10	$241,919	$209,201	$172,555	$160,794	$196,117	$36,842	0.188
20	$223,193	$188,493	$156,943	$144,274	$178,226	$35,276	0.198
26	$211,957	$176,068	$147,576	$134,363	$167,491	$34,375	0.205

[a] An average-size cotton farm in the Mississippi Delta (725 acres) is assumed where both Bt and non-Bt cotton are grown.
[b] Percentage of non-Bt cotton planted as refuge.
[c] SD = Standard Deviation.
[d] CV = Coefficient of Variation = SD/Mean.
[e] Without insecticide spray application(s).

Table 2 Total farm returns under various refuge scenarios in the Mississippi Delta, 1997-2000, with insecticide spray application(s): Regime 2[a]

z[b]	1997	1998	1999	2000	Mean	SD[c]	CV[d]
				(τ = 1)[e]			
0	$260,645	$229,908	$188,166	$177,313	$214,008	$38,480	0.180
1	$260,390	$229,207	$187,960	$177,087	$213,661	$38,399	0.180
5	$259,368	$226,400	$187,134	$176,182	$212,271	$38,088	0.179
10	$258,091	$222,891	$186,102	$175,050	$210,534	$37,729	0.179
20	$255,536	$215,874	$184,039	$172,787	$207,059	$37,113	0.179
26	$254,003	$211,664	$182,800	$171,429	$204,974	$36,813	0.180

[a] An average-size cotton farm in the Mississippi Delta (725 acres) is assumed where both Bt and non-Bt (conventional) cotton are grown.
[b] Percentage of non-Bt cotton planted as refuge.
[c] SD = Standard Deviation.
[d] CV = Coefficient of Variation =SD/Mean.
[e] With insecticide spray application(s).

Table 3 Mean and certainty equivalent (CE) returns without insecticide spray application(s): Regime 1[a]

	($\tau = 0$)[b]			
z[c]	Mean Returns ($)	Risk Aversion Coefficient	CE Returns ($)	CE/Mean
0	229,400	1	223,749	0.9754
		2	217,913	0.9499
1	227,593	1	221,977	0.9753
		2	216,184	0.9499
5	220,067	1	214,463	0.9745
		2	208,678	0.9482
10	210,549	1	204,943	0.9734
		2	199,141	0.9458
20	191,640	1	186,002	0.9706
		2	180,143	0.9400
26	180,316	1	174,668	0.9687
		2	168,787	0.9361

[a] An average-size (725-acre) cotton farm in the Mississippi Delta, 1983-2003, is examined under different non-Bt cotton (refuge) scenarios, with 1000 simulations for each scenario.
[b] Percentage of non-Bt cotton planted as refuge.
[c] Without insecticide spray application(s).

Table 4 Mean and certainty equivalent (CE) returns with insecticide spray application(s): Regime 2[a]

		($\tau = 1$)[b]		
z[c]	Mean Returns ($)	Risk Aversion Coefficient	CE Returns ($)	CE/Mean
0	229,417	1	223,805	0.9755
		2	217,999	0.9502
1	229,117	1	223,485	0.9754
		2	217,681	0.9501
5	227,638	1	221,927	0.9749
		2	216,037	0.9490
10	225,647	1	219,841	0.9743
		2	213,851	0.9477
20	221,998	1	216,007	0.9730
		2	209,836	0.9452
26	219,681	1	213,564	0.9722
		2	207,278	0.9435

[a] An average-size (725-acre) cotton farm in the Mississippi Delta, 1983-2003, is examined under different non-Bt cotton (refuge) scenarios, with 1000 simulations for each scenario.
[b] Percentage of non-Bt cotton planted as refuge.
[c] With insecticide spray application(s).