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The Net Gain to Cotton Farmers of a Natural Refuge Plan for Bollgard II® Cotton

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This paper presents an evaluation of the initial potential economic benefit at both the farm-level and to Monsanto Company of a change in refuge policy for Bollgard II® cotton. The proposed policy change is to eliminate the cotton refuge requirement for Bollgard II cotton in favor of a natural refuge. We first present an evaluative model that is appropriate for any cotton state. We then present an empirical application of the model for North Carolina. We estimate the annual per-acre, farm-level benefit to North Carolina cotton farmers, based on 2005 data as the counterfactual, to be $22.82 and the total farm-level benefit to be $13,037,614 when non-pecuniary benefits are not considered. When non-pecuniary benefits *are* taken into account, the per-acre benefit is estimated to increase to $26.90 and the total benefit to $15,379,129. The increase in revenue accruing to Monsanto Company is estimated to be $2,427,620.

Key words: biotechnology, natural refuge, Bollgard II, cotton, partial budgeting, economic benefits, non-pecuniary benefits, policy.

Introduction

This paper provides a farm-level economic analysis of a change in the refuge policy for Eastern US cotton acres from the current refuge requirements for all Bt cotton acres (20% *sprayed* non-Bt[1] refuge, 5% *unsprayed* non-Bt refuge, or 5% *embedded* non-Bt refuge) to a natural refuge policy for Bollgard II[2] cotton—where non-cotton host plant areas near the cotton field serve as the refuge. Monsanto Company has petitioned the US Environmental Protection Agency (EPA) to eliminate the non-Bt refuge in Texas, the Mid-South, and the Southeast for acres planted to Bollgard II cotton (Laws, 2006). At this writing, the petition is still pending.

The purpose of this study is to calculate the partial-equilibrium, net farm-level economic gain in North Carolina and the change in revenue to Monsanto Company if the policy change were to be approved and to demonstrate how the model developed in the study can be used in other states to evaluate the policy change. Because it is a partial-equilibrium model, any changes in either input or output prices that could be brought about by the policy change are not considered, nor are social welfare impacts. Although these two impacts could be important, they are beyond the scope of the present study.

The economic gain to farmers would come from changes on the *current Bt cotton refuge acre*s (from non-Bt to Bollgard II cotton) and *changes on the current Bollgard acres* (from Bollgard cotton to Bollgard II cotton). The latter comes about because most, if not all, of the acres planted to Bollgard varieties likely will be planted to Bollgard II varieties if the natural refuge policy is adopted (and if relative seed costs remain about the same) because planting Bollgard II cotton would no longer require cotton refuge acres to be set aside and treated differently. Therefore, Bollgard II cotton would become the economically superior option. Given that farmers can get more insect protection at a lower price, it is reasonable to assume that virtually all growers who are now planting Bollgard cotton varieties would switch to Bollgard II.

Figure 1 illustrates the changes that we would expect to occur if a natural refuge policy for Bollgard II cotton varieties were to be adopted. Figure 1-A represents the mix of total cotton acres that may be planted on a farm in a particular year. These acres are divided into several sections to represent possible cotton options that could be planted on a farm. The first section includes the conventional cotton acres that are not planted as a part of the refuge requirements. Some farmers may plant some conventional or non-Bt cotton acreage where the insect pressure is low or simply to diversify their cotton enterprise. The second section in Figure 1-A shows the Bollgard acres planted on the farm. The Bollgard II acres make up the third section, and the fourth section dis-

1. *We distinguish between conventional cotton varieties and non-Bt varieties because refuge acres can be planted to either herbicide-resistant or conventional varieties.*
2. *Bollgard® and Bollgard II® cotton are registered trademarks of the Monsanto Company.*

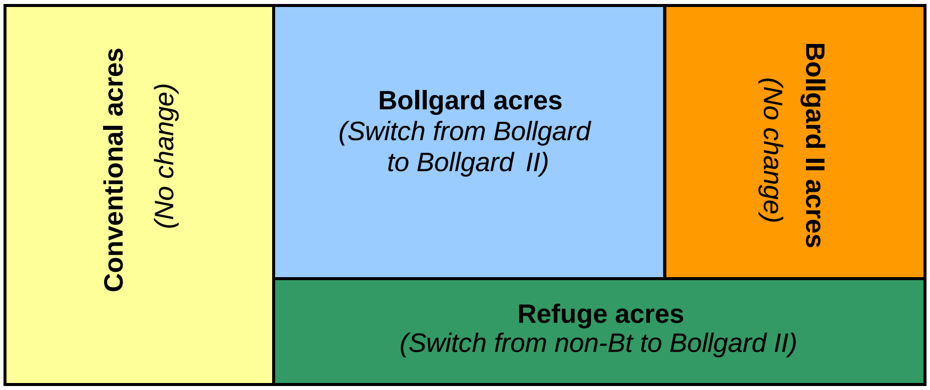

Figure 1-A. Before the natural refuge policy.

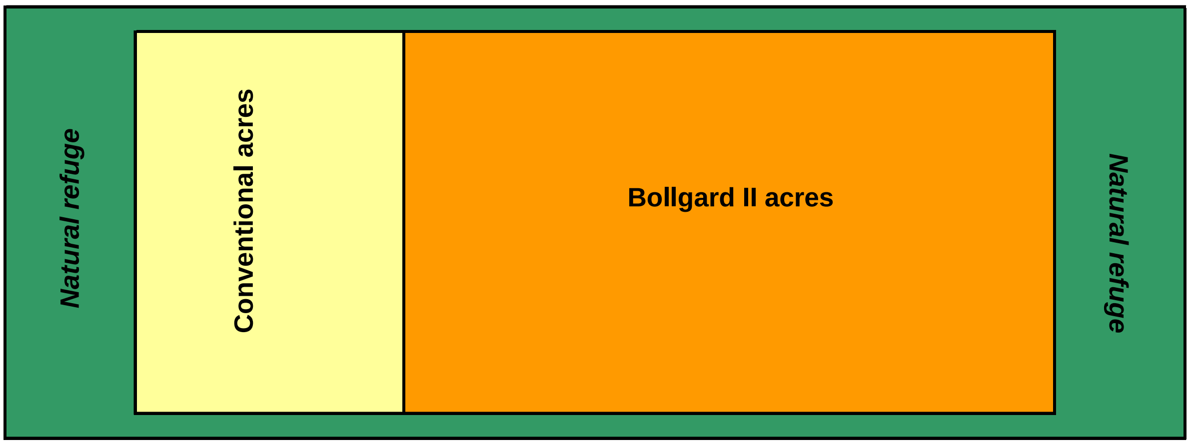

Figure 1-B. After the natural refuge policy.

Figure 1. Illustration of the changes that would take place on different portions of total cotton acres as a result of adopting a natural refuge policy for Bollgard II varieties.

plays the combined refuge acres associated with the Bollgard and the Bollgard II acres. Of course, not all farms will have all four types of acreage and, in this sense, Figure 1-A should be viewed as a stylized picture of the potential changes on a "typical" farm. Some farmers have already fully adopted Bollgard II cotton. This would mean that they would have no conventional or non-Bt acres other than those associated with the refuge requirement and would have no Bollgard acres. Their gain from the policy change would be limited to the gain on the refuge acres. Other farmers may plant only conventional varieties, in which case a refuge would not be required. They would experience no gain from the new policy. We distinguish between the different farm types in the empirical analysis below.

Figure 1-B illustrates the acreage allocation on the same farm after the natural refuge policy is approved. The conventional cotton acres would likely remain the same, although this new policy may entice a small number of producers to adopt Bollgard II on some of their conventional acres. We assume in our analysis that the proportion of conventional cotton acres remains the same. This assumption amounts to possible underestimation of the farm-level benefits, but we lack data with which to measure the likely effect on conventional acres. The economic gain (or loss) on the acres impacted by the policy change is comprised of pecuniary and a non-pecuniary components. These are discussed separately next.

Pecuniary Benefits

Pecuniary benefits are those benefits for which values are determined by market prices and thus they can be denominated in dollars in a straightforward manner. For example, if a policy change resulted in a smaller quantity of pesticides used per acre, the change can be valued by the product of the market price per unit of pesticide and the difference in the units of pesticide applied resulting from the policy change, plus the application cost savings.

The pecuniary gain on the refuge acres (Figure 1-A) is the difference in profit from switching from non-Bt to Bollgard II cotton on each of those acres. The pecuniary gain on the Bollgard acres (Figure 1-A) is the difference in profit from switching from Bollgard to Bollgard II varieties on those acres. A partial budgeting approach is employed for this part of the analysis, where we focus only on the components of profit that are impacted by the change in policy (Boehlje & Eidman, 1984). Using this approach, the net addition to profit is the sum of the additional revenue and the cost savings less the sum of any decreases in revenue and increases in cost. In the case we analyze here, all four components are present.

$$\Delta\pi_{j,t}^{A^r} = \begin{bmatrix} \left(y_{j,t}^{BGII} - y_{j,t}^{non-BT}\right) \bullet A_{j,t}^{r} \bullet \\ \left(p_{j,t}^{cot} + LDP_{j,t}^{cot}\right) \end{bmatrix} - \begin{bmatrix} \left(A_{j,t}^{r} \bullet s_j^{N,BGII} \bullet \gamma^{s,BGII}\right) - \\ \left(\sum_i A_{j,t}^{r,i} \bullet s_j^{N,non-BT} \bullet \gamma^{s,i}\right) \end{bmatrix} \bullet s^c - \left[\left(\tau^{BGII} - \tau^{non-BT}\right) \bullet A_{j,t}^{r}\right] \qquad (1)$$

$$\Delta\pi_{j,t}^{A^{BG}} = \left[\left(y_{j,t}^{BGII} - y_{j,t}^{BG}\right) \bullet A_{j,t}^{BG} \bullet \left(p_{j,t}^{cot} + LDP_{j,t}^{cot}\right)\right] - \left[A_{j,t}^{BG} \bullet s_j^{N,BGII} \bullet \gamma^{s,BGII} - \left(A_{j,t}^{BG} \bullet s_j^{N,BG} \bullet \gamma^{s,BG}\right)\right] \bullet s^c - \left[\left(\tau^{BGII} - \tau^{BG}\right) \bullet A_{j,t}^{BG}\right] \qquad (2)$$

$$\Delta\pi_{j,t}^{\left(A^r + A^{BG}\right)} = \Delta\pi_{j,t}^{A^r} + \Delta\pi_{j,t}^{A^{BG}} \qquad (3)$$

Where:

$\Delta\pi_{j,t}^{A^r}$ = the addition to profit on the refuge acres for region j in year t;

$y_{j,t}^{k}$ = the average lint yield per acre for crop type k [k={$BGII$, BG, non-Bt}];

$A_{j,t}^{r}$ = the total refuge acres for region j in year t where $A_{j,t}^{r} = \sum_i \delta_{j,t}^{Bt,i} \bullet A_{j,t}^{Bt,i}$;

$\delta_{j,t}^{Bt,i}$ = the proportion of Bt acres allocated to refuge option i for region j in year t;

$A_{j,t}^{Bt}$ = the total Bt acres (Bollgard [BG] + Bollgard II [BGII]) for region j in year t;

$p_{j,t}^{cot}$ = the average upland cotton price ($/lb) in region j and year t;

$LDP_{j,t}^{cot}$ = the average Loan Deficiency Payment (LDP) calculated as $(LR_{j,t} - p_{j,t}^{cot})$ where $LR_{j,t}$ is the average upland cotton loan rate in region j in year t;

$s_j^{N,BGII}$ = the expected number of sprays on BGII for region j;

$\gamma^{s,BGII}$ = the probability that BGII acres are sprayed in region j;

$w_{j,t}^{i}$ = the proportion of Bt acres using refuge option i in region j $\left(i.e., \sum_i w_{j,t}^{i} = 1\right)$;

$A_{j,t}^{r,i}$ = the refuge acres allocated to option i where $A_{j,t}^{r,i} = \sum_i w_{j,t}^{i} \bullet A_{j,t}^{bt,i}$;

$A_{j,t}^{BG}$ = the total acres in BG for region j in year t;

$s_j^{N,non-BT}$ = the expected number of sprays on non-Bt acres in region j;

$\gamma^{s,i}$ = the probability that the non-Bt acres in refuge option i will be sprayed;

s^c = the per-acre cost of one lepidopteran spray;

τ^k = the tech fee for crop type k;

$\Delta\pi_{j,t}^{A^{BG}}$ = the additional profit on the BG acres for region or state j in year t;

$s_j^{N,BG}$ = the expected number of sprays on BG cotton for region or state j;

$\gamma^{s,BG}$ = the probability that BG acres will be sprayed;

$\Delta\pi_{j,t}^{\left(A^r + A^{BG}\right)}$ = the total expected profit gain from the refuge policy change in region or state j in time t.

Equation 1 represents the net addition to profit on the current refuge acres in region *j* in year *t*. The additional revenue on the refuge acres is calculated by the product of the difference in yield of the k^{th} variety in the j^{th} region at time period *t*, $y^{k}_{j,t}$, from switching the refuge acres from non-Bt varieties to Bollgard II varieties (denoted by $\left[\left(y^{BGII}_{j,t} - y^{non-BT}_{j,t}\right)\right]$), and the current cotton price plus an LDP payment if one is due (denoted by $\left[\left(p^{cot}_{j,t} + LDP^{cot}_{j,t}\right)\right]$), multiplied by the total refuge acres, $A^{r}_{j,t}$. The cost *saving* is the difference in the cost of spraying, which is calculated as: the change in total number of sprays (s^{N}_{j}), expected to be needed on the refuge acres ($A^{r}_{j,t}$) in each option switched from non-Bt to Bollgard II varieties, multiplied by the expected probability of spraying those acres in region *j* in year *t*, γ^{s}, which gives $A^{r}_{j,t} \bullet s^{N,BGII}_{j} \bullet \gamma^{s,BGII}$, multiplied by the cost of one pesticide application (material and application costs), S^{c}, to give the expression:

$$\left[\left(\left(A^{r}_{j,t} \cdot s^{N,BGII}_{j} \cdot \gamma^{s,BGII}\right) - \left(\sum_{i} A^{r,i}_{j,t} \cdot s^{N,non-BT}_{j} \cdot \gamma^{s,i}\right)\right) \cdot S^{c}\right].$$

The cost *increase* is the difference in the technology fee per acre multiplied by the number of refuge acres $\left[\left(\tau^{BGII} - \tau^{non-BT}\right) \bullet A^{r}_{j,t}\right]$. Equation 2 represents the net addition to profit on the original Bollgard acres, which is a function of the same three components already described, except that the change is from Bollgard to Bollgard II. The total pecuniary gain from the policy change in region *j* at time *t* is given by equation 3, which is the sum of the two profit calculations.

Non Pecuniary Benefits

Non-pecuniary benefits are those benefits perceived by farmers but not traded in markets and thus there is not an appropriate market price that can be used to value the changes in these benefits. As a result, they are more difficult to value. Stated preference methods may be employed to obtain an estimate of the value farmers place on them (Marra & Piggott, 2006). In the case of a natural refuge policy for Bollgard II cotton, these non-pecuniary benefits could include increased human safety and environmental improvements from lower insecticide use and the value of convenience. Components of the convenience value could include a simpler production system, less concern about the timing of insecticide applications or scouting, more consistent control of the lepidopteran pests, and time savings. Some of the components of convenience may be able to be priced from market transactions, such as the reduced cost of scouting, but most cannot. Thus, convenience may be termed a "quasi-non-pecuniary" characteristic. However, its total value is important for our purposes, so we include it in the list of characteristics that requires stated preference methods with which to estimate their value. In this study, we present the net farm-level gain with and without the estimate of the non-pecuniary benefits.

An Empirical Example – North Carolina in 2005

Data

The data required to calculate the net pecuniary benefits to farmers of eliminating the current refuge regime and replacing it with a natural refuge are formidable. The requirements include yield data for Bollgard II, Bollgard, and non-Bt cotton where the number of lepidopteran sprays associated with each yield observation is recorded. In addition, these data must be available in sufficient number to achieve some reasonable level of statistical reliability. This section describes the data needed to carry out the partial budget analysis and calculate Equation 3, as well as the data sources used for the North Carolina example that follows.

1. The yield data are mean differences in various combinations of cotton variety type (for example, the mean difference in Bollgard II yield (sprayed) and non-Bt yield (sprayed), or the difference in Bollgard II (unsprayed) and Bollgard (sprayed) yield) taken from cotton variety trials conducted in North Carolina from 1999 to 2005. Most of the yield data are from North Carolina State University (NCSU) trials and were supplied by the NCSU Crop Science Department (Jackson, 2006). Some were supplied by Monsanto Company from their own on-farm variety trials in 2004. We used 1999–2005 yield data to simulate different growing seasons and pest pressure. This may bias the Bollgard II average yields downward relative to Bollgard and non-Bt yields because, in the early years before Bollgard II commercialization, the back-crossing required to make yields competitive with other cotton varieties had not yet been completed. However, we thought it more important to reflect different growing season environments in our example, so, in this sense, the total gain may be underestimated. The descriptive statistics of these paired yield differences from the variety trial data used in this analysis are in Table 1. In all comparisons but one, the Bollgard II varieties'

Table 1. Descriptive statistics of paired differences in yields used in the analysis.

	No. Obs	Mean	Stdev	Min	Max	Range
				lbs. of lint per acre		
Sprayed						
BGII – non-Bt	47	128.42*	252.45	-585.60	676.06	1,261.66
Unsprayed						
BGII – non-Bt	51	512.99*	379.34	-174.60	1,282.20	1,456.80
BGII – BG	3	80.67*	64.73	6.00	121.00	115.00
Unsprayed/sprayed						
$BGII^{u}$ – BG^{s}	3	-31.33	100.30	-117.00	79.00	196.00
Non-Bt						
Sprayed –unsprayed	51	425.78*	301.83	-320.09	895.84	1,215.93
BGII						
Sprayed – unsprayed	45	20.72	135.08	-335.78	311.58	647.35

Source: Cotton variety trails conducted in North Carolina 2005 by NCSU Crop Science and Monsanto Company.
* *Statistically significantly different from zero at the 5% level.*

yields are higher than the comparison crop type. The exception is the unsprayed Bollgard II varieties vs. the sprayed Bollgard varieties, although this difference is based on only three observations. The smallest difference is reported for sprayed vs. unsprayed Bollgard II, further supporting our hypothesis that the benefits of spraying Bollgard II in most years is likely to be small. We found the most striking differences in the comparison between unsprayed Bollgard II and unsprayed non-Bt varieties, where the unsprayed Bollgard II varieties average over 500 lbs. of lint per acre *more* than the unsprayed non-Bt varieties. The yield benefit of spraying non-Bt varieties (non-Bt, sprayed–Bt, sprayed) averaged over 400 lbs. of lint in North Carolina in 2005.

2. The average cotton price per pound of lint received by North Carolina farmers is taken to be the state-level average marketing year price reported by the US Department of Agriculture National Agricultural Statistics Service (USDA NASS, 2006). Because the North Carolina market price was below the cotton loan rate in 2005, the average cotton LDP was added to the market price farmers received, effectively making the cotton price the average loan rate. The average cotton price ($0.454/lb) plus the average LDP ($0.082/lb) across regions in North Carolina in 2005 led to an average price of cotton received by farmers of $0.536/lb. of lint, which is the average North Carolina loan rate across regions as reported by the USDA Farm Service Agency (USDA FSA, 2005). We further assume, because of the lack of sufficient data to show otherwise, that average cotton quality, and thus average cotton price, would not change with the new refuge policy. If cotton quality improves (erodes) with the traited cotton, the net benefits would be greater (less) than our results show here. We further assume that the cotton seed value just offsets the ginning fees, so there is no net benefit from any additional seed produced. We vary the cotton price in the sensitivity analysis below.

3. The total cotton acreage in North Carolina in 2005 (800,000 acres) is taken from the North Carolina Department of Agriculture and Consumer Services' (NCDA & CS) annual Agricultural Statistics report (2005), and the acres planted to Bt cotton (560,000 acres) are calculated from total cotton acreage using the proportion of cotton acres planted to insect resistant varieties (NASS, 2006). Multiplying the proportion of total cotton acres reported to be in the 5% or 20% refuge schemes (by multiplying each result by the proportion of acres required in each refuge scheme (0.05 or 0.20)) and summing the results

gives the total refuge acres in 2005 to be 46,900. The 35,170 acres planted to Bollgard II in North Carolina in 2005 were supplied by Monsanto Company.

4. The expected spray numbers by crop type were taken from the cotton variety trial data mentioned in (1) above, along with further refinements resulting from personal communication with Dr. Jack Bachelor, North Carolina State University Cotton Extension Entomologist. We assume an average of one spray per acre per season for Bollgard II (if it is sprayed at all), 1.5 sprays for Bollgard, and 2.6 sprays for non-Bt varieties in North Carolina.

5. The proportions of total Bollgard acres allocated to the different cotton refuge options were taken from data supplied by Monsanto Company. In North Carolina, 22.5% of Bt cotton farmers chose the *20% sprayed* refuge option, 72.5% chose the *5% unsprayed* refuge, and 5% chose the *5% embedded* refuge option in 2005.

6. The probabilities that non-Bt refuge acres in refuge options 1 through 3 (described below) will be sprayed for lepidopteran pests are taken from the parameters of the current requirements for each refuge option. For option 1, with the 20% sprayed refuge, the probability that any refuge acre will be sprayed in any year is set to 1.0. In other words, we assume that all of the non-Bt refuge acres in option 1 will be sprayed every year. In option 2, the 5% nonsprayed refuge option, the probability that any refuge acre will be sprayed in any year is zero. For option 3, the 5% embedded refuge, the probability that an acre is sprayed in any given year is set to 0.1. This is the probability that the associated Bollgard II acres will be sprayed since in this option the refuge acres may be sprayed only if the associated Bollgard II acres are treated for lepidopteran pests.

7. The cost of one lepidopteran spray is taken to be the average of per-acre costs reported in the latest cotton enterprise budgets for all the cotton states east of Arizona. One would expect the number of lepidopteran sprays to differ among states. However, because of competition in the insecticide markets, the per-acre cost of *one spray* should be about the same, only differing by transportation costs from the nearest manufacturer and, possibly, labor costs. The spray cost used in the main analysis, including application and insecticide costs, is $16.49 per acre. We vary this parameter in the sensitivity analysis below.

8. The 2005 technology fees for each cotton type, for all cotton states east of Arizona, were supplied by Monsanto. These are the “capped costs” that Monsanto guarantees to growers. Farmers may end up paying less than this, but no more. The additional technology fee associated with a change from non-Bt (Roundup Ready®)[3] cotton to Bollgard II (Roundup Ready) cotton averaged $9.50 per acre in North Carolina.[4] The additional technology fee in North Carolina for switching from Bollgard (Roundup Ready) to Bollgard II (Roundup Ready) varieties averaged $7 per acre. Note that, since farmers are already paying the Bollgard technology fee on these acres, we only need to account for the difference in the technology fee between Bollgard and Bollgard II in our partial budgeting framework. This fee is varied in the sensitivity analysis below.

9. The probability that any Bollgard II acres will be sprayed in a particular year for lepidopteran pests in North Carolina is assumed to be quite low. We set the parameter to 0.1 (one year in ten) as a result of personal communication with Dr. Jack Bachelor, a North Carolina State University Cotton Extension Entomologist. In addition, several sources in the literature predict that Bollgard II will need no sprays for lepidopteran pests in almost all years, and in most regions, except where there is very high pest pressure, which further supports our assumption (Horton, 2003; Hagerty, Kilpatrick, Turnipseed, Sullivan, & Bridges, 2005; Boyd & Phipps, 2005; and University of Georgia, 2005).

Pecuniary Benefits in North Carolina

Applying the data described above to Equations 1, 2, and 3 gives the estimated total pecuniary gain to North Carolina farmers resulting from the change in refuge policy for Bollgard II cotton. We find the total pecuniary gain from the converted refuge acres to be $12,528,109 per year, or $267.12 per refuge acre per year. The total

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3. *Roundup Ready® and Roundup Ready Flex® are registered trademarks of the Monsanto Company.*
4. *Since almost all biotech cotton acres in North Carolina in 2005 had the Roundup Ready trait, we use the tech fees associated with the relevant insect protection trait(s) stacked with the Roundup Ready trait in the analysis.*

Table 2. Values of non-pecuniary characteristics of new biotech crops.

	Value of the change from old technology to new technology ($/acre/year)			
Characteristic	**Median**	**Mean**	**Std. Dev.**	**Skewness**
Corn rootworm survey: n = 367				
Old technology: Conventional corn		*New technology: YieldGard rootworm corn*		
Time savings	0.588	0.997	1.390	4.047
Equipment savings	0.400	0.724	0.969	3.087
Operator and worker safety	0.429	0.991	1.623	3.670
Environmental safety	0.208	0.787	1.565	4.606
More consistent stand	0.800	1.773	2.862	4.111
Total non-pecuniary	**2.425**	**5.272**		
National soybean survey: n = 113				
Old technology: Conventional soybeans		*New technology: Roundup Ready (RR) soybeans*		
Operator and worker safety	0.913	1.660	2.026	1.367
Environmental safety	1.304	1.961	2.201	1.257
Total convenience	3.333	4.158	3.690	1.114
Total non-pecuniary	**5.000**	**7.779**		
North Carolina herbicide-tolerant survey: n = 52				
Old technology: Conventional crops		*New technology: RR corn, cotton, and soybeans*		
Operator and worker safety	2.361	2.923	2.783	0.884
Environmental safety	1.666	2.720	2.660	0.955
Total convenience	5.000	7.793	7.818	2.588
Total non-pecuniary	**10.000**	**13.437**		
Roundup Ready Flex cotton survey: n = 55				
Old technology: RR cotton		*New technology: RR Flex cotton*		
Operator and worker safety	0.000	0.602	2.469	4.190
Environmental safety	0.000	0.802	2.556	4.810
Total convenience	5.000	7.187	9.027	2.300
Total non-pecuniary	**5.000**	**8.591**		

Source: Marra and Piggott (2006) & unpublished survey data (various years).

pecuniary gain on the acres planted currently to Bollgard varieties that would switch to Bollgard II varieties after the natural refuge policy is implemented equals $509,505 per year, or $0.97 per Bollgard acre. The sum of the two sources of pecuniary impacts is $13,037,614, or $22.82 per impacted acre.

Non-Pecuniary Benefits in North Carolina

Studies of non-pecuniary benefits using stated preference techniques have been conducted for other crop/event combinations, such as YieldGard® Rootworm corn, Roundup Ready soybeans, herbicide-tolerant crops, and Roundup Ready Flex cotton. Unfortunately, these benefits have not yet been measured for the Bollgard II event. We know from these past studies that farmers do value these non-pecuniary aspects of crop biotechnologies, and therefore it is reasonable to assume that they have value to farmers in this case as well. Even if it is not possible to pinpoint the value, some insights might be gained as to the magnitude of the value farmers place on the non-pecuniary characteristics in the Bollgard II-natural refuge case by examining the values from the previous studies. The first three studies are summarized in Marra and Piggott (2006). The Roundup Ready Flex cotton non-pecuniary values are taken from a recent survey of cotton farmers conducted by Marra and Piggott in late 2005. Table 2 summarizes the estimated non-pecuniary values from the previous studies. Since the distribution of values is positively skewed in every case, the median is the most representative esti-

Table 3. Total gain to North Carolina farmers of a new, natural refuge policy for Bollgard II cotton varieties.

	Total acres	Value/ acre	$/state/year
On current BG and BGII refuge acres:			
Non-Bt to Bollgard II			
Pecuniary gain	46,900	$267.12	$12,528,109
Non-pecuniary gain	46,900	$7.57	$355,033
Sub total			$12,883,142
On current Bollgard acres:			
Bollgard to Bollgard II			
Pecuniary gain	524,830	$0.97	$509,505
Non-pecuniary gain	524,830	$3.79	$1,986,482
Sub total			$2,495,987
Total gain per Year to North Carolina farmers		**$26.90**	**$15,379,129**
Pecuniary gain:			
Non-Bt to Bollgard II	46,900	$267.12	$12,528,109
Bollgard to Bollgard II	524,830	$0.97	$509,505
Sub total			$13,037,614
Non-pecuniary gain:			
Non-Bt to Bollgard II	46,900	$7.57	$355,033
Bollgard to Bollgard II	524,830	$3.79	$1,986,482
Sub total			$2,341,515
Total gain per Year to North Carolina farmers		**$26.90**	**$15,379,129**

mate for each value. The medians of the total value of the individual non-pecuniary characteristics derived from these surveys range from $2.43 to $10.00 per acre. The midpoint is $7.57 per acre. We use this midpoint as the assumed per-acre additional value of the change in the non-pecuniary characteristics on the *refuge acres* in the empirical example. We use half the midpoint, $3.79, as the assumed additional non-pecuniary value of the per-acre change on the current Bollgard acres. The non-pecuniary gain, therefore, is estimated to be $355,033 per year on the refuge acres and $1,986,482 on the Bollgard acres. The total non-pecuniary gain to North Carolina farmers is, therefore, estimated to be $2,341,515 per year.

Table 4. Sensitivity analysis of gains per acre to natural refuge.

Cotton price ($/lb)	Control cost ($/acre) 8.25		16.49		24.74	
	BGII-non-BG technology fee ($/acre) 9.50	19.00	9.50	19.00	9.50	19.00
	Net gain ($/acre)					
0.536	15.40	14.62	26.90	26.12	38.42	37.64
0.600	16.23	15.45	27.23	26.95	39.25	38.47
0.700	17.54	16.76	29.04	28.26	40.55	39.78
0.800	18.84	18.06	30.34	29.56	41.86	41.08

Net Gain to North Carolina Farmers from the Policy Change

Total Net Gain

The total net gain North Carolina farmers would have received in 2005 as a result of the refuge policy change is the sum of the pecuniary and non-pecuniary gains on the *refuge acres* and the *Bollgard acres*. The total net gain, assuming no non-pecuniary benefits, is $13,037,614 per year, or $21.91 per impacted acre. The total net gain that includes our estimate of the non-pecuniary benefits is $15,379,129 per year or $26.90 per impacted acre per year. Table 3 summarizes these gains.[5]

Sensitivity Analysis

In Table 4 we present some sensitivity analysis on the important parameters of the model. In this analysis we vary the control cost per acre from half ($8.25/acre) to 1.5 times the cost used in the main analysis, which is $24.74/acre. The technology fee charged by Monsanto Company for its Bollgard II cotton, was doubled from the 2005 level used in the main analysis to $19.00 per acre, and the expected cotton price was varied from the lowest possible price a farmer could receive in 2005, the average loan rate across North Carolina regions of $0.536/lb, up to the level of $0.80/lb. It is evident in Table 4 that changes in expected cotton price and the level of the technology fee do not have much influence on the per-acre gain from the policy change. The parameter that appears to influence the net gain the most is the cost of spraying for lepidopteran pests. Recall that this is

5. *Intermediate calculations involved in arriving at these estimates are available from the authors upon request.*

a savings in the model because acres are being switched from a technology that requires insecticide treatments to a technology that requires little or no treatments. A doubling of the control cost per acre from $16.49 to $24.74 results in an increase in net gain of about $11.52, or 70% per acre per year, (with cotton price at $0.536/lbs and technology fee at $9.50 per acre), whereas doubling the technology fee results in an approximately $0.78 decrease in net gain per acre, or 3% (with cotton price at $0.536/lbs and control cost of $16.49 per acre). Increasing the cotton price from $0.536/lbs to $0.80/lbs (49%) increases the net gain by about $3.44, or 13%, per acre (with control costs of $16.49 per acre and technology fee of $9.50 per acre).

Conclusion

The net gain at the farm level with only pecuniary factors considered is estimated to be $13.0 million per year, or $22.82 per acre. The farm-level benefit, pecuniary and non-pecuniary, to North Carolina cotton farmers for a change in refuge policy for Bollgard II cotton, based on 2005 data as the counterfactual, is estimated to be $26.90 per acre. This amounts to a total farm-level benefit of $15.4 million per year for North Carolina. As we have noted, this estimate is probably conservative for several reasons. The gain in revenue to Monsanto is estimated to be $2,427,620, or about 16 to 18% of the amount gained at the farm level. This is calculated by multiplying the relevant change in tech fee by the acres affected. The total net gain in North Carolina at the farm level and to Monsanto is estimated to be $15.5 million if non-pecuniary gains are assumed to be zero (a lower bound estimate), or $17.8 million if non-pecuniary gains are assumed to be equal to the median value of the earlier studies shown in Table 2.

The estimated gains from the proposed policy change depend on the maintained hypotheses employed to calculate them. One of these is that, for 2005, the difference in unsprayed Bollgard II and sprayed Bollgard yields in North Carolina is negative (-31 lbs/acre). This may be due partly to employing experimental variety trial data from as far back as 1999. As Bollgard II yields continue to improve relative to other cotton types, this difference should lessen or even reverse, making the total gain per year in most states higher in the future. Another maintained assumption is that Bollgard II cotton is only sprayed if an unusually high lepidopteran pest infestation occurs. While we conclude this to be about once in ten years in North Carolina, unusually high pest pressure could occur more or less often in other growing regions and this difference should be taken into account in further analyses.

Perhaps the most crucial maintained hypothesis is that the natural refuge concept will work as well as the current refuge policy in maintaining a pool of insects susceptible to the Bt toxins. Scientific studies so far seem convincing that this is the case. However, if there turn out to be additional costs to the new refuge policy in the form of insect-resistance development, they would have to be weighed against the benefits outlined here.

The calculations in this example apply to one of the northern tier of cotton states and may be fairly representative of that region. However, the state-level gains for other states, especially in the Southeast below the Santee-Cooper lake system in South Carolina, in the Lower Delta, and in the Coastal Bend and West Texas growing regions, are likely to be different. We encourage others in those regions to use our model (Equations 1-3) with their own regional data to evaluate the farm-level impacts of this important policy change. Even without these further evaluations, we believe it is reasonable to assume that the annual total gain to cotton farmers across the cotton belt if the natural refuge policy is adopted would be substantial.

References

Boehlje, M., & Eidman, V. (1984). *Farm Management*. New York: John Wiley & Sons.

Boyd, M., & Phipps, B. (2005). *Cotton insect management guide – 2005*. Columbia: University of Missouri. Available on the World Wide Web: http://aes.missouri.edu/delta/muguide/ctnmgtgs.pdf.

Hagerty, A., Kilpatrick, A., Turnipseed, S., Sullivan, M., & Bridges, W. (2005). Predaceous arthropods and lepidopteran pests on conventional, Bollgard and Bollgard II cotton under treated and disrupted conditions. *Environmental Entomology, 34*(1), 105-114. Retrieved March 1, 2006, from http://www.bioone.org/archive/0046-225X/34/1/pdf/i0046-225X-34-1-105.pdf.

Horton, T. (2003, November). Early BGII tests show promise. *Cotton Farming*. Retrieved March 1, 2006, from http://www.cottonfarming.com/home/2003_DecCF-Production.html.

Jackson, R. (2006). [Cotton variety trials data]. Unpublished raw data, Department of Crop Science, North Carolina State University, Raleigh, NC.

Laws, F. (2006, February 6). *Monsanto proposes natural refuge for Bollgard II cotton.* Delta Farm Press. Retrieved February 6, 2006, from http://deltafarmpress.com/news/060206-bollgard-refuge/.

Marra, M.C., & Piggott, N.E. (2006). The value of non-pecuniary characteristics of crop biotechnologies: A new look at the evidence. In Just, Alston, and Zilberman (Eds.), *Regulating Agricultural Biotechnology: Economics and Policy* (pp.145-178). New York: Springer-Verlag Publishers.

North Carolina Department of Agriculture and Consumer Services (NCDA & CS). (n.d.). *North Carolina Agricultural Statistics, 2005*. Retrieved March 18, 2006, from http://www.agr.state.nc.us/stats/crop_fld/fldannyr.htm.

United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). (2006). *Crop Production, January 12*. Retrieved March 18, 2006, from http://usda.mannlib.cornell.edu/usda/nass/CropProd//2000s/2006/CropProd-01-12-2006.pdf.

United States Department of Agriculture Farm Service Agency (USDA FSA). (2005). *Crop Upland Cotton Warehouse Loan Rates*. Retrieved March 18, 2006, from http://www.fsa.usda.gov/Internet/FSA_File/2005upland cottonlr.pdf.

University of Georgia, 2005. *2006 Cotton Guide: Insect Management*. Retrieved March 3, 2006 from University of Georgia, Department of Agricultural and Environmental Sciences, Commodities Web site: http://commodities.caes.uga.edu/fieldcrops/cotton/2006cottonguide/insectmanagement.pdf.

Author Notes

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