Rent Creation and Distribution from the First Three Years of Planting *Bt* Cotton

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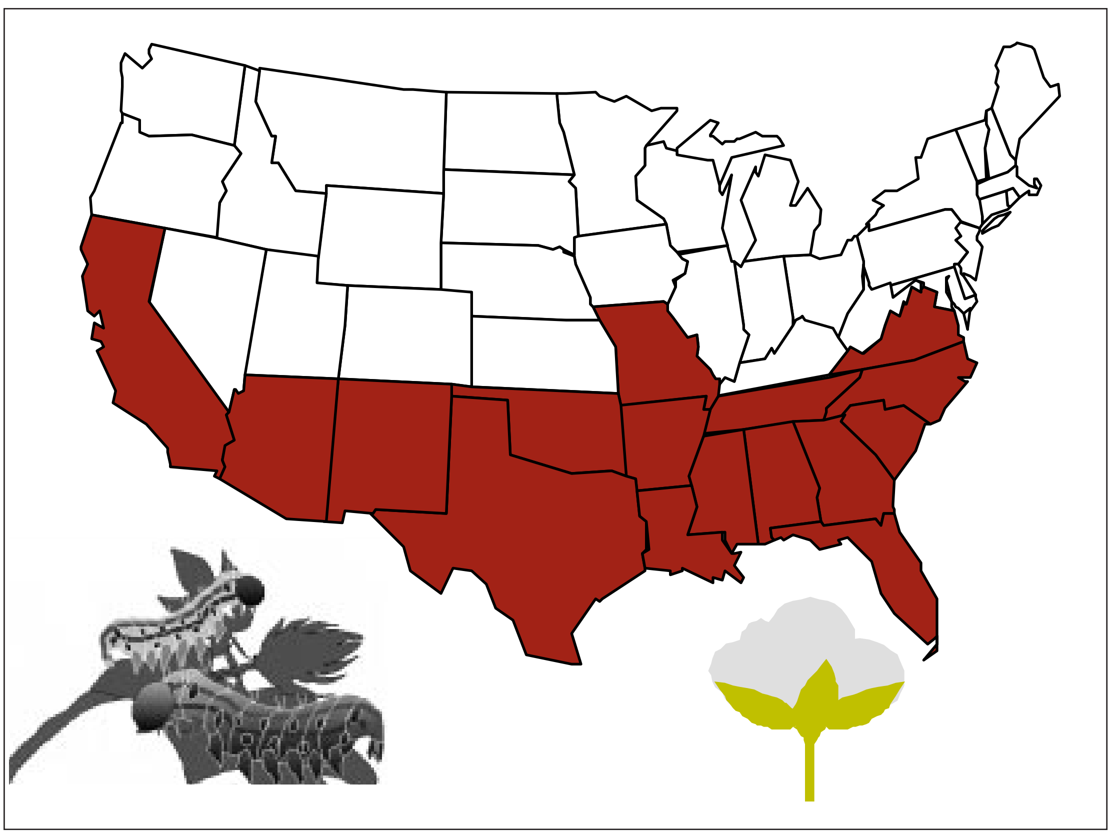

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Summary

We used an alternative data set from Plexus Marketing Research, Inc. and Timber Mill Research, Inc. to reestimate rent creation and distribution from the adoption of *Bt* cotton in 1996. This alternative data set allowed us to compare the sensitivity of the estimates for 1996 presented in a previous paper. Results from both estimations indicate that farmers gain between 43% and 59% of all rents created from the introduction and adoption of *Bt* cotton. In contrast, the innovators (Delta and Pine Land, and Monsanto) gain between 47% and 26% of all rents in 1996.

Preliminary results from the estimation of rent creation and distribution for 1998 indicate that farmers and innovators share almost equally the rents created by adopting *Bt* cotton. Farmers gain 43% whereas the innovators gain 47% of total rents. Regionally, there were winners and losers from the adoption of *Bt* cotton in 1998. Regions with low adoption rates, such as California and Missouri, lost because farmers suffered a price reduction of cotton lint without having the benefits of the technology. We performed a sensitivity analysis to evaluate results by reducing the yield and/or cost change assumptions in half. In the worst-case scenario, where yield increases and cost reductions were reduced by 50%, farmers still captured 21% of the total rents, whereas the innovators gained 74% of total rents.

Results for the three-year analysis have been fairly consistent. Farmers share the rents created by the technology almost equally with innovators, even when a monopolistic structure for the input market is assumed. Improving the reliability of these results requires modeling rents using an *ex ante* framework where risk is considered in the analysis. The naive estimations presented here and in our other papers need to be formalized into a model that introduces the characteristics discussed earlier. There is a need to validate results from surveys whose intention is to measure cost and yield benefits or losses due to technology. This is the only way that we can assure that measurements of the benefits and losses of the technology are measured accurately. Finally, there is an urgent need to quantify the environmental externalities, particularly to quantify the benefits of decreased pesticide releases into the environment. These benefits may be significant and are not currently included in the framework presented here.

Introduction

Life science or biotechnology firms have taken advantage of practical biotechnology protocols and strengthened intellectual property laws in plant innovations to deliver genetically modified varieties (GMVs) to the U.S. and rest-of-the-world (ROW) farmers. These changes in biotechnology development and delivery have increased transgenic plant releases. From 1996, the date of the first commercial transgenic success, to 1998, more than 48 transgenic cotton varieties have been released in the United States. Subsequent to the successful U.S. introduction, some of these varieties have been introduced into China, Australia, Mexico,and other major cotton-producing countries (Pray 1997, James 1998). While many recognize the positive incentive effect of increased appropriability of intellectual property, concern has been expressed for the effects of these legal and scientific changes on seed industry structure and concentration, on seed prices, and on the welfare of farmers (Butler and Marion 1985, Doyle 1985, and Kloppenburg 1988).

In this paper we reestimated rent creation and distribution from *Bacillus thuringiensis (Bt)* cotton in 1996 using survey data, and compared these results with those obtained by Falck-Zepeda, Traxler, and Nelson (1999a) for the same year using a different data set. We provided preliminary surplus estimates for *Bt* cotton in 1998. Subsequently, we compared the preliminary results from 1998 with both estimates from 1996, and with the estimate from the 1997 planting season presented in Falck, Traxler, and Nelson (1999b). Finally, we discussed some of the implications of the estimated distribution of rents on farmers and the impacts of biotechnology varieties in the U.S. and abroad on social welfare.

Background

Bt cotton was planted on 2.7 million acres in the U.S. in 1998, up from 2.3 and 1.8 million acres in 1996 and 1997 respectively (Table 1). *Bt* technology has also spilled over to farmers abroad, and was planted on 514,000 thousand acres outside of the U.S. in 1998, up from 202,000 acres in 1997 (Table 2). In 1997 and 1998, Australia had the highest acreage of planted *Bt* cotton, with 165,000 and 200,000 acres, respectively. In 1998, the second largest acreage was planted in China, at 156,000 acres. *Bt* cotton is also being planted in Mexico and South Africa, and has been tested successfully in Argentina (Videla et al 1999).

In the United States, adoption of *Bt* cotton varieties and of other genetically modified varieties has varied across states. Adoption has varied from 1% in Virginia to 80% in Florida (Table 3).[1] Some regions with low adoption of *Bt* varieties such as North Carolina, Texas, Tennessee, and Virginia, have higher adoption rates of other GMVs such as BXN® and Roundup Ready® resistant cotton varieties. This may indicate that in these regions the budworm-bollworm complex (BBW) is not economically important or that the available varieties are not appropriate for the region.

Table 4 presents a list of studies made in the United States and abroad evaluating *Bt* cotton under different biotic conditions and locations, followed by a brief discussion of a sample of previous studies conducted to evaluate the effectiveness of *Bt* cotton.

In 1995, farmers in Alabama had one of the worst cotton insect losses in history due to the pyrethroid-resistant BBW complex. This is in marked contrast to the following year, which had the lowest amount of insecticide applications on record (Smith 1997). Alabama was an early adopter of the technology in the United States, and although all the reductions in insecticide application cannot be attributed to the *Bt* technology, it did play a role in this significant reduction. Smith (1998) indicated that in 1997 *Bt* varieties were treated between two and four times, whereas conventional varieties were treated six to eight times. A majority of the applications on *Bt* cotton in 1997 were to control fall armyworms

[1] Adoption estimates from the USDA/AMS publication "Cotton Varieties Planted" differ in some states from the estimates made by entomologists in Williams (1997, 1998, 1999).

Table 1. Adoption of *Bt* cotton in the United States, selected states.

State	Percent adoption *Bt*		
	1996	1997	1998
Alabama	74	70	69
Arizona	23	61	71
Arkansas NE	1	12	1
Arkansas SE	38	13	30
Florida	43	60	56
Georgia	30	38	47
Louisiana	15	38	60
Mississippi	39	43	60
New Mexico	*	1	35
North Carolina	*	6	12
Tennessee	1	3	19
Percent adoption *Bt* U. S.	14	17	25
Total U.S. *Bt* (000 acres)	1,851	2,294	2,732
Total U. S.(000 acres)	13,052	13,462	10,713

Note: * = less than 0.5% adoption.
Source: Williams 1997-99.

Table 2. International plantings of *Bt* cotton, 1996-98.

Cotton	*Bt* cotton (000 acres)		
	1996	1997	1998
USA	1,851	2,272	2,411
Australia		165	200
China		0	156
South Africa		0	29
Mexico		37	111
Argentina		0	20
Total ROW		202	514
Total world acres planted to cotton (a)	83,500	82,800	80,600

Source: James, except (a) USDA/ERS 1998. ROW = rest of the world.

Table 3. Percent adoption of cotton GMVs in the United States, selected states, 1998.

State	Percent adoption *Bt* cotton	Percent adoption stacked Bt/RR	Percent adoption BXN® cotton	Percent adoption Roundup Ready cotton	Total percent adoption cotton GMVs
Alabama	59	2	*	11	72
Arkansas	14	*	28	2	44
Florida	80	*	*	6	87
Georgia	30	18	5	17	70
Louisiana	69	2	8	1	80
Mississippi	52	7	7	2	69
New Mexico	*	*	11	2	13
North Carolina	2	2	4	30	38
Texas	7	1	0	27	34
Tennessee	5	2	40	16	63
Virginia	1	*	3	19	24
USA	18	3	6	17	45

Note: * = less than 0.5% adoption.
Source: USDA/AMS 1998.

Table 4. Results of evaluation studies of *Bt* cotton in the United States and the rest of the world.

Source	Region	Year study conducted	Type of study	*Bt* yield	*Bt* yield advantage (%)	*Bt* insect. cost exclud. tech. fee ($/acre)	Non-Bt insect. cost ($/acre)	Insecticide cost reduction exclud. tech. fee ($/acre)	Bt cotton net returns adv. ($/acre)	No. of *Bt* treat./ acre	No. of non-*Bt* treat./ acre	Comments
Benedict	Texas	1992-1995	Experimental plots		14.0							
Monsanto Bollgard Cotton Update 1996	Southeast	1995-1997	Experiment and field studies	933	13.9	14.1	26.6	12.4	54.5			
Monsanto Bollgard Cotton Update 1996	Delta	1995-1997-	Experiment and field studies	964	5.0	48.0	86.3	38.3	37.5			
Monsanto Bollgard Cotton Update 1996	East Texas	1995-1997	Experiment and field studies	543	11.0	33.6	41.5	7.9	11.0			
Monsanto Bollgard Cotton Update 1996	Cotton Belt	1995-1997	Experiment and field studies	813	9.5	31.9	51.4	19.5	33.7			
Wier, Mullins, Mills (1998)	Southeast	1995-1997	On-farm comparison	933	12.2	14.1	26.6	12.5	54.5			
Wier, Mullins, Mills (1998)	Delta	1995-1997	On-farm comparison	964	4.7	48.0	86.3	38.3	35.5			
Wier, Mullins, Mills (1998)	East Texas	1996-1997	On-farm comparison	543	9.9	32.6	41.5	8.9	11.0			
Davis, Layton, Verner, and Little (1995)	Mississippi	1994	Experimental plots		19.0			78.0				
Edens et al (1998)	SW Tennessee	1994	Farmer survey			0	16.0	16.0				Value is for 96/4 refugia option
Edens et al (1998)	NW Tennessee	1994	Farmer survey			0	17.0	17.0				Value is for 96/4 refugia option
Shaunak	Mississippi	1994	Experimental plots					12.5 - 79.1				
Davis, Layton, Verner, and Little (1995)	Mississippi	1995	Experimental plots					94.8				
Edens et al (1998)	NW Tennessee	1995	Farmer survey			0	39.0	39.0				Value is for 96/4 refugia option

.

Table 4. continued

Source	Region	Year study conducted	Type of study	*Bt* yield	*Bt* yield advantage (%)	*Bt* insect. cost exclud. tech. fee ($/acre)	Non-Bt insect. cost ($/acre)	Insecticide cost reduction exclud. tech. fee ($/acre)	Bt cotton net returns adv. ($/acre)	No. of *Bt* treat./ acre	No. of non-*Bt* treat./ acre	Comments
Edens et al (1998)	SW Tennessee	1995	Farmer survey			0	57.0	57.0				Value is for 96/4 refugia option
Gibson et al	Mississippi	1995	Experimental plots						94.8			
Bacheler, Mott, and Morrison (1998)	North Carolina	1996	Producer and consultant survey						-9.0	0.1	3.1	115 pairs of *Bt* & conventional on-farm fields managed by consultants plus 32 producers & extension agents. No yield differences used in analysis
Bryant, Robertson, and Lorenz (1998)	Arkansas	1996	On-farm comparison						79.0			Observations in 8 farms in 8 separate counties in Arkansas
Cooke and Freeland	Mississippi Delta	1996	Farmer survey	919	-5.1	87.8	87.2					
Davis, Layton, Verner, and Little (1995)	Mississippi	1996	Producer survey						16.2			
Zelinsky and Kerby	U.S.	1996	Experimental plots		7.7							
Zelinsky and Kerby	Southeast	1996	Experimental plots		7.3							
Zelinsky and Kerby	North Delta	1996	Experimental plots		2.7							
Zelinsky and Kerby	South Delta	1996	Experimental plots		4.0							
Zelinsky and Kerby	North Texas	1996	Experimental plots		16.4							

Table 4. continued

Source	Region	Year study conducted	Type of study	*Bt* yield	*Bt* yield advantage (%)	*Bt* insect. cost exclud. tech. fee ($/acre)	Non-Bt insect. cost ($/acre)	Insecticide cost reduction exclud. tech. fee ($/acre)	Bt cotton net returns adv. ($/acre)	No. of *Bt* treat./ acre	No. of non-*Bt* treat./ acre	Comments
Delta and Pine Land	South Texas	1996	Experimental plots		5.9							
Delta and Pine Land	Far West	1996	Experimental plots		11.4							
Edens et al (1998)	SW Tennessee	1996	Farmer survey			0	10.0	10.0				Value is for 96/4 refugia option
Edens et al (1998)	NW Tennessee	1996	Farmer survey			0	13.0	13.0				Value is for 96/4 refugia option
Plexus (1997)	Alabama	1996	Consultant survey		13.2			4.7				
Plexus (1997)	Arkansas	1996	Consultant survey		2.5			6.6				
Plexus (1997)	Georgia	1996	Consultant survey		12.7			9.9				
Plexus (1997)	Louisiana	1996	Consultant survey		-2.6			26.6				
Plexus (1997)	Mississippi	1996	Consultant survey		7.9			15.2				
Plexus (1997)	North Carolina	1996	Consultant survey		-3.6			13.2				
Plexus (1997)	Texas	1996	Consultant survey		4.0			6.2				
Gibson et al	Mississippi	1996	Producer survey									
Marra, Carlson, and Hubbell (1998)	Alabama	1996	Producer survey		2-44			28.9				
Marra, Carlson, and Hubbell (1998)	Georgia	1996	Producer survey		8.3			61.7				

Table 4. continued

Source	Region	Year study conducted	Type of study	*Bt* yield	*Bt* yield advantage (%)	*Bt* insect. cost exclud. tech. fee ($/acre)	Non-Bt insect. cost ($/acre)	Insecticide cost reduction exclud. tech. fee ($/acre)	Bt cotton net returns adv. ($/acre)	No. of *Bt* treat./ acre	No. of non-*Bt* treat./ acre	Comments
Marra, Carlson, and Hubbell (1998)	South Carolina	1996	Producer survey		12.5			63.1				
Marra, Carlson, and Hubbell (1998)	North Carolina	1996	Producer survey		-3.4			59.4				
Monsanto Cotton Update	U.S.	1996	Experimental plots		7.0							
Rejesus, Greene, Hamming, and Curtis	South Carolina	1996	Experimental plots						17.1			
Stark	Georgia	1996	Producer survey						100.3			
Wier, Mullins, and Mills (1998)	Mississippi	1996	On-farm comparison	898	5.6	31.4	58.2	26.9	24.7			
Bacheler, Mott, and Morrison (1998)	North Carolina	1997	Producer and consultant survey						-8.0	0	2.0	115 pairs of *Bt* & conventional on-farm fields managed by consultants plus 32 producers & extension agents. No yield difference used in analysis
Bryant, Robertson, and Lorenz (1998)	Arkansas	1997	On-farm comparison						-63.0			Observations in 8 farms in 8 separate counties in Arkansas
Bryant, Robertson, and Lorenz (1998)	Arkansas	1997										
Plexus (1998)	Alabama	1997	Consultant survey		0.3			7.1				
Plexus (1998)	Georgia	1997	Consultant survey		22.0			27.3				

Table 4. continued

Source	Region	Year study conducted	Type of study	*Bt* yield	*Bt* yield advantage (%)	*Bt* insect. cost exclud. tech. fee ($/acre)	Non-Bt insect. cost ($/acre)	Insecticide cost reduction exclud. tech. fee ($/acre)	Bt cotton net returns adv. ($/acre)	No. of *Bt* treat./ acre	No. of non-*Bt* treat./ acre	Comments
Plexus (1998)	Louisiana	1997	Consultant survey		8.1			26.4				
Plexus (1998)	Mississippi	1997	Consultant survey		4.9			35.8				
Plexus (1998)	N. Carolina	1997	Consultant survey		4.8			11.6				
Plexus (1998)	S. Carolina	1997	Consultant survey		2.3			20.5				
Plexus (1998)	Texas	1997	Consultant survey		2.6			9.6				
Plexus (1998)	Arkansas	1997	Consultant survey		-0.4			18.7				
Layton, Stewart, Williams, and Reed (1997)	Mississippi	1997	Producer survey							3.1	0.9	106 pairs of on-farm fields. Total sprays were *Bt* = 5.11 and non-*Bt* = 6.34. Different sprays need to control "other" bugs.
Layton, Stewart, Williams, and Reed (1997)	Mississippi	1997	Producer survey							1.9	0.4	51 pairs of on-farm fields. Total sprays were *Bt* = 3.5 and non-*Bt* = 4.84
Layton, Stewart, Williams, and Reed (1997)	Mississippi	1997	Producer survey							4.4	1.3	51 pairs of on-farm fields. Total sprays were *Bt* = 6.50 and non-*Bt* = 7.84
Roof and Durant Carolina	South	1997 survey	Producer							3.4	1.4	10 on-farm locations

Table 4. continued

Source	Region	Year study conducted	Type of study	*Bt* yield	*Bt* yield advantage (%)	*Bt* insect. cost exclud. tech. fee ($/acre)	Non-Bt insect. cost ($/acre)	Insecticide cost reduction exclud. tech. fee	Bt cotton net returns adv. ($/acre)	No. of *Bt* treat./ acre	No. of non-*Bt* treat./ acre	Comments
Wier, Mullins, Mills (1998)	Mississippi	1997	On-farm comparison	984	8.5	52.4	82.6	28.2	53.7			
Layton, Stewart, Williams, and Long	Mississippi	1998	In-farm plot comparison							1.2	5.2	
Magaña et al	Mexico	1998	Experiment station plots		13-29				4-30			
Mullins and Mills (1999)	NC, SC, and VA	1998	Producer and consultant survey	878	7.6	8.7	36.4		41.7	1.2	3.7	20 pairs of fields
Mullins and Mills (1999)	TN and North AR	1998	Producer and consultant survey	871	10.8	63.1	95.1		60.7	1	3.6	11 pairs of fields. Total sprays to control insects: *Bt* = 6.5; non-*Bt*= 8.3
Mullins and Mills (1999)	GA and AL	1998	Producer and consultant survey	936	4.2	33.6	74.0		38.7	0.6	4.5	12 pairs of fields. Total sprays to control insects: *Bt* = 2.8; non-*Bt* = 5.8
Mullins and Mills (1999)	MS, LA and South AR	1998	Producer and consultant survey	856	2.6	77.3	125.4		36.0	1.7	6.2	66 pairs of fields. Total sprays to control insects: *Bt* = 7.9; non-*Bt* = 10.1
Mullins and Mills (1999)	Midsouth and SE U.S.	1998	Producer and consultant survey	870	4.44	58.5	100.4		39.9	1.4	5.3	109 pairs of fields. Total sprays to control insects: *Bt* = 6; non-*Bt* = 8.3
Smith (1999)	Alabama	1998	Entomologist estimates			6-28	60-120			2-4	6-8	

SW = Southwest, NW = Northwest, NC = North Carolina, SC = South Carolina, VA = Virginia, AR = Arkansas, TN = Tennessee, GA = Georgia, MS = Mississippi, SE = Southeast.

and stink and other plant bugs. In addition to the difference in the number of applications, cost per application differed for both types of varieties. Average application cost for conventional varieties ranged between $10 and $15 an acre, but application costs for *Bt* varieties averaged $3-7 per acre. The difference in average cost per application is mainly due to the chemistry and urgency required to control the different pests attacking *Bt* and conventional cotton.

Using farm survey data from Mississippi, Gibson et al (1997) estimated that the average net return for *Bt* cotton in 1996 was $246.30 per acre. For non-*Bt* cotton average net returns were $230.08 per acre, a difference of only $16.23 per acre. We made an adjustment for refugia, yielding an adjusted average difference in per acre net returns of $11.17, still in favor of *Bt* cotton varieties. In South Carolina, Rejesus et al (1997) estimated that earnings from *Bt* cotton varieties varied between $17.12 and $68.44 per acre more than conventional varieties depending on planting location. These results are derived from on-farm experimental sites. Stark (1997) estimated that in 1996, Georgia producers who adopted *Bt* earned $100.30 more per acre. This figure was a result from 2.5 less applications ($27.50 per acre) and an additional 114 pounds of lint ($72.80 per acre) from using *Bt* cotton varieties.

Carlson, Marra, and Hubbell[2] surveyed approximately 300 producers in Alabama, Georgia, South Carolina, and North Carolina for the 1996 planting season to evaluate the impact of *Bt* variety adoption in the Southeast. Researchers reported that average yields were 11.4% higher in fields planted with *Bt* varieties than with conventional varieties. Application costs were reduced by an average of $33, whereas insecticide applications were reduced by almost 72%. Additional profits from the adoption of *Bt* cotton varied between $59 and $111 per acre.

Bacheler compared 307 pairs of fields planted with *Bt* and conventional cotton in North Carolina over three years. Over the three years, *Bt* fields averaged 0.8 applications of insecticides while conventional fields were treated an average of 2.6 times. Layton et al surveyed 78 *Bt* and 55 conventional cotton fields in Mississippi. Results of the survey showed that *Bt* fields sustained significantly less caterpillar-induced boll damage. At the same time, *Bt* fields received fewer foliar insecticide treatments (1.2) for control of the BBW complex compared with fields planted to conventional varieties (5.2).

In 1998, Mullins and Mills surveyed 109 sites where growers, consultants, and university/extension researchers kept records of costs and yields of similarly managed and closely located *Bt* and conventional fields. These fields were located in Southern and Southeastern states. Overall, average yields on *Bt* fields were 37 pounds higher than on fields planted with conventional varieties. The number of insecticide applications on *Bt* fields was lower than in conventional fields, although the number of insecticide applications for pests not controlled by *Bt* varieties was higher. The average insecticide control costs were $15.43 lower on *Bt* fields, after paying the technology fee. The net economic advantage of *Bt* varieties was approximately $40 per acre. In Mexico, Magaña et al (1999) found that yields of transgenic *Bt* cotton were between 13-29% higher for transgenics on 1-hectare plots, with no significant differences in operating expenses between varieties, and with a difference in gross returns that varied between 4% and 30%.

The Empirical Model

We modeled the cultivation of *Bt* cotton in 1998 as occurring in a large open-economy with technology spillovers. We assumed linear supply and demand, and a parallel shift in supply from the new technology (Alston, Norton, and Pardey 1995). In developing an innovation model under imperfect competition, Moschini and Lapan (1997) indicate that monopoly profits are not included in regular Marshallian measurements of surplus such as the methodology presented by Alston, Norton, and Pardey. Monopoly profits are rents and thus should be included in the estimation of rent creation. We

[2] An electronic version of this paper is Marra, Carlson, and Hubbell.

attempted to measure monopoly profits produced by the downstream seed input supplier and the biotechnology firms. A complete description of the model and the methodology used can be seen in Falck, Traxler, and Nelson (1999a).

Next we presented the strategy for estimating the surpluses created by the introduction of *Bt* cotton that accrue to farmers, domestic and international consumers, and innovators. First, the technology-induced cotton supply shift was estimated for each of the 30 cotton-producing regions using data on yield, cost savings net of increased seed costs, and adoption rates. Second, the impact of the new technology on world and regional prices was calculated. This implies the estimation of a counterfactual price reduction to isolate the effect of the technology-induced supply shift from other exogenous changes in supply and demand. This price change will differ from observed changes in world price. It answers the question: what would the *ceteris paribus* world price be due to a technology shock? Third, Marshallian surplus distribution in domestic and international markets was estimated using procedures explained below. We used the economic surplus approach as presented by Alston, Norton, and Pardey. Their approach is well established in the agricultural economics literature and allows research-induced Marshallian surpluses generated in an output market to be partitioned between producers and consumers. Finally, monopoly profit accruing to Monsanto, and Delta and Pine Land was estimated.

Data Sources

Data for the reestimation of economic rents in 1996 come from a survey of consultants made by Plexus Marketing Research, Inc. and Timber Mill Research Inc. in 1996. Consultants were compensated for the collection of data on costs and yields of paired on-farm *Bt* and non-*Bt* fields. Fields in both cases were selected so that they had similar agronomic, production, and crop rotation histories. The survey was repeated in 1997, from which we estimated rents (Falck, Traxler and Nelson, 1999b). For the preliminary estimates for 1998 we used results from the survey presented by Mullins and Mills. Since this survey is not comprehensive, we used the average of yield and cost changes of the states with available information to provide an estimate of the states with no information. Additionally, because there is limited information publicly available for farmers in the rest of the world, we assumed for this paper that ROW obtained 50% and 100% of the efficiency obtained by U.S. farmers. Results from a study by Magaña et al in Mexico (1999) indicate that *Bt* varieties were relatively well adapted to the environmental and biocide conditions in a state in Mexico.

To estimate monopoly profit accruing to Monsanto, and Delta and Pine Land, we assumed that the seed multiplication process was identical for transgenic and conventional varieties. We also assumed that the market for conventional seed cotton is competitive, so that the conventional market price is equivalent to the marginal cost of producing seed, *c*. We considered that any increase in price above the price of conventional seed (*c*) contributes to monopoly profits. Thus total monopoly profits can be estimated by the formula: $Q_{Bt}(P_{Bt} - c)$. In this formula Q_{Bt} and P_{Bt} are the quantity and price of *Bt* seed, and *c* is the marginal cost of producing seed or the price of conventional varieties. These figures represent gross *Bt* revenue – no administrative, marketing, or intellectual property rights (IPR) enforcement costs were deducted.

To estimate the allocation of monopoly profits between Monsanto, and Delta and Pine Land, we used information contained in Monsanto, and Delta and Pine Land annual reports for 1997 (Falck, Traxler, and Nelson 1999a). Estimates from these reports indicated that Monsanto passed approximately $5.11 per acre back to Delta and Pine Land for using their germplasm. Along with the $2 per acre seed premium, this provided Delta and Pine Land with a gross revenue per acre of $7.11. Monsanto's share of gross profit was estimated by subtracting $5.11 from the $32 technology fee, resulting in a gross revenue of $26.89 per acre for Monsanto.

The observed world price (P_1) was 0.63/pound in 1996, $0.84/pound in 1997, and $0.53/pound in 1998. The share of U.S. production consumed domestically was 0.59 in 1996, and 0.6 in 1997 and

1998 (USDA/ERS, 1996, 1997, 1998). The elasticities used in this study came from previous studies. We used a value of 0.84 estimated by Taylor for the elasticity of supply, e_{USA}. We used a value of 0.101 from Kinnucan and Miao (1999) for the domestic demand elasticity (h_{USA}). For the export elasticity, h_{EB}, we used an estimate of 1.62 from Duffy, Wohlgenant, and Richardson (1990). For e_{ROW} and h_{ROW}, the ROW supply and demand elasticities, we used the estimates of 0.15 and 0.13, respectively from Sullivan, Wainio, and Roningen (1989).

Results

Results of our reestimation of the 1996 cotton crop year using the Plexus survey data are presented in columns 2 and 3 of Table 5. According to our estimation using the Plexus survey data, *Bt* cotton in 1996 created $134 million in additional surplus. Farmers received $58.2 million representing 43% of total surplus. Monsanto gained $49.7 million, whereas Delta and Pine Land gained $13.1 million, representing 37% and 10% of total surplus, respectively. U.S. consumers gained almost $7.6 million. In contrast, ROW consumers gained $12.8 million, and ROW producers lost $7.6 million. The difference between the estimation using the Plexus data and our previous study (in columns 4 and 5 of Table 5) is due to gains received by U.S. farmers. Using the Plexus survey, the farmers' share decreased to 43%, a loss of 16% from the Falck, Traxler, and Nelson (1999a) estimate. Monsanto, and Delta and Pine Land combined shares increased from 26% to 47%. Differences between both estimates are the result of lower figures for yield differences between the Plexus data and the different sources of data used in the Falck, Traxler, and Nelson (1999a) study. In addition, the 1996 estimates were the mean results of a simulation that considered the effects of elasticities in the estimation of rents. As described by Alston, Norton, and Pardey (1995), converting experiment yield gains to cost decreases by dividing by the elasticity of supply introduces the problem of "inflated" results with small values of an elasticity (less than 1). Our 1996 estimate assumed that the elasticity of supply had a triangular distribution with a minimum value of 0.30 (Gardner 1976), a most likely value of 0.84 and a maximum value of 1.61 (Taylor 1993). The simulation model sampled from this triangular distribution considering values as low as 0.3. With values as low as this, average values for rent creation would tend to be higher than by just using the average value of 0.84.

Data used to estimate rents for 1998 are presented in Table 6. The last column on this table presents the regional estimate of farmer surplus.[3] In our estimates most states gained from the planting of *Bt* cotton in 1998, except for Northeast Arkansas, California, Missouri, and some regions in Texas. Results of the estimation of economic surplus for the 1998 planting of *Bt* cotton, assuming the same efficiency assumption, are presented in Table 7. Columns 2 and 3 present results for observed yield and cost changes in the Mullins and Mills survey. Total surplus in 1998 amounted to $200 million. U.S. consumers captured $12.6 million and U.S. farmers gained $86.4 million. In contrast, ROW producers lost $12.6 million, whereas ROW consumers gained $21.1 million . Results of our estimations are percentage-wise identical to the results obtained in 1996 using Plexus data and other data sources.

To examine the sensitivity of our estimates to the cost and yield changes data, we estimated rent distribution assuming that cost and/or yield changes decreased in half for all states. Thus, columns 4 and 5 present the results of decreasing observed yield changes for each region by 50%. Columns 6 and 7 present results where cost changes are reduced for each region by 50%, and Columns 8 and 9 present results for decreasing both yield and cost changes by 50%. Results of the sensitivity analysis presented in columns 4 through 7 indicate that, as expected, our results are more sensitive to the yield change assumption. In the 50% decrease in yield change and cost change scenarios, farmers' share of rents decreases to 36% and 30%, respectively, whereas

[3] Results for the ROW farmers obtaining 50% of the efficiency as U.S. farmers were almost the same as in the 100% assumption presented earlier, thus they are not presented in this paper.

Table 5. Estimates of economic surplus due to the introduction of *Bt* cotton in 1996.

	Using Plexus (1997) data		Results from Falck, Traxler, and Nelson (1999a)	
	Mean values ($ 000)	Percent of total	Mean values ($ 000)	Percent of total
U.S. consumer surplus	7.6	6	21.6	9
U.S. farmer surplus	58.3	43	140.8	59
Monsanto	49.8	37	49.8	21
Delta and Pine Land	13.2	10	13.2	5
ROW producer surplus	(7.6)	—	21.6	—
ROW consumer surplus	12.8	—	36.5	—
Net ROW surplus	5.3	4	15.0	6
Total world surplus	134.1	100	240.2	100

Table 6. Percent adoption, total acres, yield difference, cost reduction and farmer surplus, 1998.

State/Region	Percent adoption Bt cotton[a]	Total acres planted to Bt cotton	Percent yield difference (*Bt* – non-*Bt*)[b]	Percent pest. cost reduction (*Bt* – non-*Bt*)[b]	1998 farmer surplus (000 acres)[a]
Alabama North	75	185	4	11	4,617
Alabama Central	73	80	4	9	2,132
Alabama South	62	190	4	9	3,927
Arizona	71	250	4	6	10,004
Arkansas Northeast	1	513	11	6	-831
Arkansas Southeast	30	342	3	8	3,293
California	*	826	4	5	-3,012
Florida	56	80	4	11	1,753
Georgia	47	1,300	4	8	27,174
Louisiana	60	540	3	10	10,976
Mississippi Delta	44	565	3	8	8,687
Mississippi Hills	82	365	3	9	10,798
Missouri	1	350	4	10	-547
New Mexico	35	60	4	10	1,351
North Carolina	12	695	8	7	2,428
Oklahoma	10	120	4	11	217
South Carolina	40	280	8	5	5,634
Tennessee	19	450	11	5	4,628
Texas Coastal Bend	12	425	4	10	1,050
Texas Far West	22	159	4	11	914
Texas High Plains	*	1,900	4	11	-2,844
Texas Lower Rio Grande	5	215	4	10	-7
Texas North Central	23	240	4	15	1,353
Texas Rolling Plains	17	180	4	15	633
Texas South Central	29	140	4	7	1,317
Texas South Rolling Plains	35	170	4	18	1,539
Virginia	3	91	8	6	2
Total					$97,188

Note: *= less than 0.5 % adoption.
[a] Source: Williams 1999.
[b] Source: Mullins and Mills 1999.

Table 7. Estimates of economic surplus due to the planting of *Bt* cotton in 1998.

	Results using survey yield and cost changes[a]		50% yield decrease		50% cost change decrease		Decrease in both cost and yield change by 50%	
	Value ($ million)	Percent of total	Value ($ million)	Percent of total	Value ($ million)	Percent of total	Value ($ million)	Percent of total
U.S. consumer surplus	14.0	7	9.9	6	6.9	4	3,639.1	3
U.S. farmer surplus	97.2	46	68.3	38	49.3	32	26,425.7	21
Monsanto	73.5	34	73.5	41	73.5	48	73,471.0	59
Delta and Pine Land/other	19.4	9	19.4	11	19.4	13	19,411.2	15
ROW producer surplus	(14.0)		(9.9)		(6.9)		(3,639.2)	
ROW consumer surplus	23.4		16.5		11.4		6,065.2	
Net ROW surplus	9.3	4	6.6	4	4.6	3	2,426.1	2
Total world surplus	213.4	100	177.7	100	153.7	100	125,373.0	100

[a] Table assumes rest-of-the world (ROW) farmers have the same efficiency as U.S. farmers. Assuming lower efficiencies yielded similar results.

the innovators' share increases to 56% and 63% for the same scenarios.

A drastic reduction in either the yield or cost assumption makes *Bt* cotton less attractive to farmers in some regions. Reducing by half both cost and yield increases the innovators' share to 74% from the previous scenarios, whereas farmers' share decreases to 21%, consumers' share decreases to 2%, and rest-of-the-world net share decreases to 3%. These are additional benefits to farmers because of the adoption of the technology. Farmers are capturing an extra 21% of additional rent in the worst-case scenario due to the adoption of the technology.

Discussion

Results of our estimations of distribution of rents in 1996, for 1997 (presented in Table 8), and for 1998, are similar. According to these estimates farmers and monopolist innovators share almost equally the additional rents created by the innovation. The only time when this result changes is when yield and cost decreases are reduced enough, making it difficult to justify using *Bt* in some regions, as shown in our simulation of decreasing by half the yield and/or cost changes. As would apply to any *ex post* analysis, our estimations do not take into consideration risk preferences and premiums. From the standpoint of arriving at a true estimate of the value of *Bt*, there is a need to evaluate gains/ losses of adoption in an *ex ante* analysis where risk is taken into consideration. We concur with entomologists (Benedict) that *Bt* cotton is a risk management tool, and thus even if a region may have "lost" in an *ex post* analysis, in an *ex ante* analysis this would have been a winning strategy.

In this model there are two opposing effects that determine whether or not farmers in a region win or lose from the adoption of *Bt* cotton. These effects are the price reduction to farmers due to the introduction/adoption of the technology, and the additional net benefits (or losses) due to yield and cost changes. The price effect is a reduction in the price of cotton lint induced by the supply shift. Both nonadopting and adopting farmers suffer a decrease in the price they receive for their product. The yield-cost change will provide additional net benefits if farmers obtain: (a) a yield increase, (b) a cost decrease, or (c) both effects at the same time. Farmers may still be able to obtain a net–benefit even if they do not obtain a yield increase or a cost decrease, if one component is positive enough to compensate farmers for a negative effect in the other component. For example, the total cost of using *Bt* cotton may be higher than conventional varieties after taking into consideration the de-

Table 8. Economic surplus results, 1997 cotton crop.

	Values (000)	Percent of total
U.S. consumer surplus	14,015	7
U.S. farmer surplus	80,023	42
Monsanto	67,118	35
Delta and Pine Land/other	17,733	9
ROW poducer surplus	(12,137)	
ROW consumer surplus	23,360	
Net ROW surplus	11,222	6
Total world surplus	190,111	100

Note: ROW producers obtain same yield increases and cost decreases as U.S. producers.
Source: Falck, Traxler and Nelson 1999b.

Table 9. Average number of insecticide applications to control BBW complex, selected states.

State	1993	1994	1995	1996	1997	1998
Alabama Central	4.00	8.00	9.6	0.02	0.16	1.18
Alabama North	4.00	2.70	6.7	0.18	0.56	0.52
Alabama South	7.00	5.00	5.9	0.13	1.00	2.32
Florida	5.30	5.30	5.7	1.21	0.95	2.00
Georgia	2.70	4.30	3.4	1.67	2.53	1.54
Louisiana	4.70	4.80	4.7	3.85	3.23	3.48
Mississippi Delta	4.50	4.80	4.5	2.50	3.21	3.13
Mississippi Hills	4.00	3.10	8.2	1.51	1.33	1.55
North Carolina	2.50	3.60	2.6	3.07	1.98	3.04
South Carolina	4.90	4.40	4.7	4.19	3.32	3.44
Texas South Central	4.17	3.66	2.6	2.33	1.69	0.64

Source: Cotton Insect Losses, Proceedings Beltwide Cotton Conferences, 1993-1998.

creases in pesticide applications and paying the technology fee and seed premiums, yet a positive yield difference may make the net gains in rents positive.

An important caveat of this study is that the methodology implemented does not consider the potential externalities generated by adopting the technology. An important positive externality is the reduction in the amount of pesticides released into the environment. In Table 9, for example, after the adoption of the *Bt* technology average applications for controlling the BBW complex decreased for some states. Gianessi and Carpenter (1999) used insecticide usage data from USDA/National Agricultural Statistics Service (NASS), and insect control recommendations from five cotton-producing states were used to identify the insecticides that growers were likely to use to control target pests of *Bt* cotton. Insecticide use was compared between the years when the varieties were introduced, 1995 and 1998. The researchers estimated that the overall reduction in insecticide use for controlling the BBW complex was 2.0 million pounds, or 12% of all insecticides used in the selected states in 1995.

Summary and Conclusions

We used an alternative data set from Plexus Marketing Research, Inc. and Timber Mill Research, Inc. to reestimate rent creation and distribution from the adoption of *Bt* cotton in 1996. This alternative data set allowed us to compare the sensitivity of the estimates for 1996 presented in a previous paper. Results from both estimations indicate that farmers gain between 43% and 59% of all rents created from the introduction and adoption of *Bt* cotton. In contrast, the innovators (Delta and Pine Land, and Monsanto) gain between 47% and 26% of all rents in 1996.

Preliminary results from the estimation of rent creation and distribution for 1998 indicate that farmers and innovators share almost equally the rents created by adopting *Bt* cotton. Farmers gain 43% whereas the innovators gain 47% of total rents. Regionally, there were winners and losers from the adoption of *Bt* cotton in 1998. Regions with low adoption rates, such as California and Missouri, lost because farmers suffered a price reduction of cotton lint without having the benefits of the technology. We performed a sensitivity analysis to evaluate results by reducing the yield and/or cost change assumptions in half. In the worst-case scenario, where yield increases and cost reductions were reduced by 50%, farmers still captured 21% of the total rents, whereas the innovators gained 74% of total rents.

Results for the three-year analysis have been fairly consistent. Farmers share the rents created by the technology almost equally with innovators, even when a monopolistic structure for the input market is assumed. Improving the reliability of these results requires modeling rents using an *ex ante* framework where risk is considered in the analysis. The naïve estimations presented here and in our other papers need to be formalized into a model that introduces the characteristics discussed earlier. There is a need to validate results from surveys whose intention is to measure cost and yield benefits or losses due to technology. This is the only way that we can assure that measurements of the benefits and losses of the technology are measured accurately. Finally, there is an urgent need to quantify the environmental externalities, particularly to quantify the benefits of decreased pesticide releases into the environment. These benefits may be significant and are not currently included in the framework presented here.

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Appendix

The formulas for the counterfactual world price (P_0), relative price change (Z), and changes in domestic and ROW producer and consumer surpluses are:

$P_0 = P_1 / \{1 - [e_{USA} K_{WORLD} / [e_{USA} + S_{USA} h_{USA} + (1- S_{USA}) h^{EB}] \},$

$Z = -(P_1-P_0) / P_0 = e_{USA} K_{WORLD} / [e_{USA} + S_{USA} h_{USA} + (1- S_{USA}) h^{EB}] ,$

$DCS_{USA} = P_0 C_{USA,0} Z (1 + 0.5 Z h_{USA}),$

$DPS_{USA} = P_0 Q_{USA, 0} (K_{USA} - Z) (1 + 0.5 Z e_{USA}),$

$DCS_{ROW} = P_0 C_{ROW, 0} Z (1 + 0.5 Z h_{ROW}),$

$DPS_{ROW} = -P_0 Q_{ROW, 0} (K_{ROW} – Z) (1 + 0.5 Ze_{ROW}),$

$DUSAS = DCS_{USA} + DPS_{USA},$

$DROWS = DCS_{ROW} + DPS_{ROW}$

where P_1 is the observed world price, k_{WORLD} is the result of adding k_{USA} and k_{ROW} ,and $K_{WORLD} = k_{WORLD} / P_0$. e_{USA} is the U.S elasticity of supply of the output, h_{USA} is the absolute value of the U.S. demand elasticity, h^{EB} is the absolute value of the elasticity of export demand, h_{ROW} is the absolute value of ROW demand elasticity, and e_{ROW} is the ROW supply elasticity. S_{USA} is the share of U.S. production consumed domestically, Q_{USA} and C_{USA} are quantities of cotton produced and consumed in the United States, Q_{ROW} and C_{ROW} are quantities of cotton produced and consumed in the rest of the world. DCS_{USA} is the change in consumer surplus in the U.S., DPS_{USA} is the change in producer surplus in the U.S., DCS_{ROW} is the change in consumer surplus in the rest of the world, DPS_{ROW} is the change in producer surplus for the foreign sector, DUSAS is the change in total surplus in the United States, and DROWS is the change in the rest-of-the-world surplus.