ADOPTION OF BT COTTON: REGIONAL DIFFERENCES IN PRODUCER COSTS AND RETURNS

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Abstract

This study uses a quadratic programming model to estimate the impacts of Bt cotton adoption on consumer benefits, cotton program outlays, and producer returns, by state and adoption status. Three scenarios were considered simulating low, moderate, and high impacts of Bt cotton adoption. For the moderate scenario, U.S. benefits from Bt adoption grew from $44 million in 1996 to $66 million in 1998. Annual benefits to U.S. cotton purchasers ranged between $46–$55 million. Benefits to Bt adopters grew from $57 million in 1996 to $97 million in 1998. Losses to non-adopters fell from -$59 million in 1996 to -$8 million in 1998 as rising commodity program payments mitigated the impact of lower prices.

Introduction

In 1995, the year prior to Bt cotton introduction, tobacco budworms, cotton bollworms, and pink bollworms reduced U.S. cotton yields by over 4% (Williams, 1996) – or by a quarter billion dollars worth of cotton. Nationally, cotton growers averaged 2.4 insecticide applications to control bollworms and budworms, with the average ranging from 6.7 in Alabama to virtually none in California (Williams, 1996). Costs averaged nearly $10 per acre per application.

Previous studies have credited Bt cotton adoption with sizeable gains for U.S. producers. Gianessi and Carpenter (1999) estimate benefits of $92.7 million. Traxler and Falck-Zepeda (1999) estimate producer benefits ranging from $80–$141 million. These studies derived aggregate benefit measures based on yield gain and pest control cost-saving estimates from a variety of more micro-level, agronomic, and partial budgeting studies. Estimates of Bt adoption impacts from micro-level studies vary widely by region, year, and study. For example, ReJesus et al. (1997) report a change in net acre returns from Bt cotton adoption from specific sites in South Carolina ranging from a $104.92 gain in 1996 to a -$81.68 loss in 1997. Gianessi and Carpenter (1999) report estimates of net gains in Mississippi that range from $16.22 to $94.83. Stark (1997) reports a yield gain of 11% from Bt adoption in Georgia, while Falck-Zepeda et al. (1999) cite results of a survey estimating yield gains of 22%.

This study reports some results of a price-endogenous mathematical programming model analysis of the size and distribution of economic benefits of Bt cotton adoption. Three simulation scenarios were considered representing low, moderate, and high impacts on adopter yields and insecticide application savings. Because the high degree of variability in the estimates of Bt cotton's performance across time and place, our approach generates lower bound, mid-range, and upper bound estimates of Bt adoption impacts. The framework allows one to identify how the gap between lower and upper bound estimates is affected by differences in assumptions about Bt cotton's performance in different regions.

Methods

The modeling approach used is similar to quadratic programming studies of the impacts of pesticide cancellations (Deepak et al., 1996; Sunding, 1996). First, we developed a model of U.S. cotton production, dividing production into 31 state and sub-state regions (Table 1). The model assumes that each region has constant average (and marginal) costs and yields in a given year. Each region faces an output capacity constraint representing limits imposed by local agronomic conditions and technology. Within regions, yields and costs differ between Bt cotton adopters and non-adopters (Tables 1 and 2). Within each region, producers allocate land between Bt and conventional cotton. A region allocates land to Bt cotton only if it is more profitable than conventional cotton. Land is allocated to Bt cotton up to a maximum adoption ceiling. This ceiling matches actual regional Bt adoption rates for each year from 1996–8. The adoption ceilings are exogenous to the model, but would vary according to regional pest pressures, availability of Bt varieties adapted to local conditions, producer familiarity with the technology, and variables affecting producers' expected adoption gains, such as price expectations.

U.S. cotton supply is a "step function" comprised of 62 steps, representing Bt cotton adopters and non-adopters in each region. The step function is combined with functions for U.S. cotton demand and Rest of World (ROW) supply and demand. These four functions determine the equilibrium world price of cotton, as well as ROW cotton production, overall cotton demand, and demand for U.S. cotton exports. The average U.S. farm price differs from the world price, reflecting transport costs, quality differences, and government market interventions. Changes in the world price may not be transmitted exactly to changes in the U.S. price. Following Sullivan et al. (1989) we adopt a baseline transmission elasticity of one. Domestic producers receive price premiums or discounts, modeled as fixed differences from the U.S. farm

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price. The model also accounts for the fact that producers receive Loan Deficiency (POP) payments or market gain payments if the adjusted world price falls below the loan rate.

In the baseline models, total and Bt cotton acreage, average yields, production, exports, prices, costs, program payment rates, and payment levels are calibrated to actual data. To estimate the impacts of Bt cotton adoption, we ask the counterfactual question, "What would regional yields and costs have been had Bt cotton not been adopted?" The model is then constrained so producers can only grow conventional cotton. The impacts of Bt cotton adoption are measured by the differences between the baseline and constrained models.

Data

Data on U.S. upland cotton acreage, average yields, prices received, domestic consumption, and exports for the years 1996–8 were obtained from National Agricultural Statistical Service databases. Estimates of domestic and export demand elasticities and foreign supply elasticities were based on Duffy et al. (1990), Duffy and Wohlgenant (1991), and Sullivan et al. (1989). Data on commodity program payments came from the Price Support Division of USDA's Farm Services Agency. Data on Bt cotton adoption rates and average pest control costs came from Williams (1996, 1997, 1998). Data on other costs were developed from USDA's *Farm Cost and Returns Survey* and from cooperative extension crop budgets. Data on seed prices and Bt technology fees came from Williams (1996, 1997, 1998), from state crop budgets, and from Bt cotton studies cited in Gianessi and Carpenter (1999).

Data used to construct estimates of lower bound, moderate, and upper bound impacts of Bt adoption on yields and pest control costs came from a variety of sources. These include partial budgeting studies cited in Gianessi and Carpenter (1990), impacts compiled by Falck-Zepeda and Traxler (1998) and by Falck-Zepeda et al. (1999), and state cooperative extension studies. For regions with no available adoption studies, and to supplement existing studies, we followed the procedure of Eddleman et al. (1995). They estimated yield gains and pesticide application cost savings based on historic yield losses and pest control costs for bollworm, tobacco budworm, and pink bollworm reported in Williams (various years).

Table 1 shows the yield gains for Bt adopters for three scenarios: low, moderate, and high impact. It also shows Bt adoption rates, based on Williams (1998), as a percent of harvested acres for 1998. Table 2 shows the pesticide application cost savings (excluding technology fees and seed price premiums) used in the low, moderate, and high impact scenarios. The lower and upper bound impact estimates represent *regional* lower and upper bounds. In any given year, one might expect individual producers to experience impacts outside of these bounds. In the three scenarios, we have paired the low, moderate, and high yield increase and cost reduction impacts. For example, the moderate scenario assumes both moderate yield increases and moderate pest control cost savings. Also, in a given scenario, impacts are of the same type over the whole three-year period.

Results

Production increases ranged from 0.6% (low impact, 1996) to 2.9% (high impact, 1998). Export increases ranged from 1.5% (low impact, 1996) to 7.2% (high impact, 1998). Greater production lowered the cotton price, ranging from -0.5 cents (low impact, 1996) to -2.1 cents (high impact, 1998). Commodity program payments mitigated the impact of lower market prices to a large extent in 1998. Under the moderate impact scenario, the U.S. farm price of cotton declined by between -0.8 and -1.25 cents. This suggests that adoption of Bt cotton accounts for only about 3–5% of the 24-cent drop in U.S. cotton prices from 1995 to 1999.

Table 4 shows impacts of Bt cotton adoption on producer and consumer groups under the moderate impact scenario. The impacts of Bt adoption on producers consist of four effects: (a) a *yield effect*, (b) a *cost effect*, (c) a *market price effect*, and (d) a *commodity program payment effect.* Bt cotton adopters face all four effects, while non-adopters experience only the market price and program payment effects. Benefits to adopters grew from $57 million in 1996 to $97 million in 1998. Losses to non-adopters fell from -$59 million in 1996 to -$8 million in 1998 as rising commodity program payments mitigated losses from lower prices. For U.S. cotton producers as a whole, impacts ranged from a net loss of -$1.6 million in 1996 to a net gain of $20 million in 1997 and a gain of $88 million in 1998.

Annual benefits to U.S. purchasers of cotton ranged between $46–$55 million. Prices were sufficiently high so cotton producers did not receive program payments in 1996. Lower prices triggered program payments beginning in 1997 and to a larger extent in 1998. Under the moderate impact scenario, Bt adoption increased government payments by nearly $78 million in 1998. Net benefits to the Rest of World are on the order of $20–$30 million dollars annually.

Table 5 shows impacts of Bt cotton adoption on producer returns by state under the moderate impact scenario for 1998. Georgia accounts for one-third of adopter gains. Alabama, Arizona, Georgia, Louisiana, and Mississippi account for three-quarters of the adopter gains. Texas and California account for two-thirds of the non-adopter losses. Although the Texas High Plains and the San Joaquin Valley account for a quarter of cotton acreage, there has been virtually no Bt adoption in these areas. Lack of Bt varieties adapted to local growing conditions is a constraint in the High Plains. The San Joaquin Valley also faces less pressure from pests that Bt varieties control (Gianessi and Carpenter, 1999).

Discussion

Our estimates of the net global benefits to cotton producers and consumers from Bt cotton adoption ranged from $20–$26 million per year under the low impact scenario, $72–$88 million per year under the moderate impact scenario, and $146–$175 per year under the high impact scenario. Traxler and Falck-Zepeda (1999) estimated these benefits to range from $104–$177 million in 1997. Carpenter and Gianessi estimated the gains to U.S. producers from Bt cotton adoption to be $92.7 million in 1998. They estimated benefits of yield increases and reduced pest control costs, holding the price of cotton fixed. Their estimate is quite close to our 1998 estimate of adopter gains of $96.8 million. In 1998 commodity program payments kept the effective price farmers received relatively fixed.

Economists have long recognized how commodity programs affect the size and distribution of gains from technological innovation in agriculture (Alston et al., 1988; Oehmke, 1988). A comparison of impacts from 1996 and 1998 in Table 4 demonstrates this effect vividly. In 1996 price supports were not in effect. Because of falling prices, non-adopter losses cancelled adopter gains. In 1998, price supports prevented the *effective price* cotton growers received from falling much at all. Under price supports, producer gains from innovation are much larger. Yet, they shift the cost of lower prices from producers to taxpayers.

Under the low impact scenario, Bt adoption increased production 0.6–1.1%, while under the high impact scenario, production increased 1.8–2.9% (Table 3). Three states (Georgia, Alabama, and Mississippi) accounted for about two-thirds of the difference between the low and high impact scenarios. Another five states (Arkansas, Arizona, Louisiana, South Carolina, and Texas) accounted for over a quarter of the difference. These states account for the bulk of total Bt cotton acres. If more precise estimates of yield impacts could be obtained for a relatively small number of states, then the difference between upper and lower bound estimates of production and price impacts could be substantially reduced.

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Table 1. Yield assumptions used in model simulations with Bt cotton adoption rates.

Region	Percent yield increase for Bt adopters			Bt acres as a percent of harvested acres, 1998
	Low impact	Moderate impact	High impact	
Southwest				
AZ, Southeast	4	5.5	7	4.4
AZ, West	4	5.5	7	39.9
AZ, Central	4	5.5	7	87.7
CA, Imperial Valley	4	5.5	7	23.5
CA, Sacramento Valley	0.5	1	7	0.0
CA, San Joaquin Valley	0.5	1	7	0.0
NM	3	7	10	36.6
Southern Plains				
OK	7	8.5	10	10.0
TX, Coastal Bend	3	4	11	12.2
TX, Far West	5	6.5	7.5	27.2
TX, High Plains	1	2	3	0.1
TX, Lower Rio Grande	3	4	11	4.9
TX, North Central	3	4	11	52.1
TX, North Rolling Plains	3	4	8	14.8
TX, Southern Blacklands	3	10	14	57.9
TX, South Rolling Plains	3	5	10	61.7
Delta				
AR, Northeast	3	7	11	1.2
AR, Southeast	3	7	11	25.8
LA	4	6	8	61.4
MS Delta	3	5	12	44.0
MS Hills	3	5	12	82.0
MO	3	4	7	0.9
Southeast				
AL, Central	3	7	14	69.1
AL, North	3	7	14	76.8
AL, South	3	7	14	55.7
FL	4	8	14	56.1
GA	7	8	14	46.2
NC	2	4.5	7	11.9
SC	3	8	13	39.2
TN	6	8	11	18.8
VA	5	6.5	7	3.0

Table 2. Bt cotton pest control cost reduction assumptions used in model simulations.

Region	Reduction in pest control costs for Bt adopters		
	Low impact	Moderate impact	High impact
Southwest			
AZ, Southeast	$ 30.00	$34.00	$65.00
AZ, West	$ 25.00	$34.00	$50.00
AZ, Central	$ 30.00	$34.00	$55.00
CA, Imperial Valley	$ 25.00	$34.00	$50.00
CA, Sacramento Valley	$ 5.00	$10.00	$15.00
CA, San Joaquin Valley	$ 5.00	$10.00	$15.00
NM	$ 21.00	$26.00	$39.00
Southern Plains			
OK	$ 21.00	$28.00	$35.00
TX, Coastal Bend	$ 12.00	$15.00	$18.00
TX, Far West	$ 12.00	$16.00	$23.50
TX, High Plains	$ 12.00	$18.00	$22.00
TX, Lower Rio Grande	$ 14.50	$26.00	$36.00
TX, North Central	$ 14.50	$15.00	$17.00
TX, North Rolling Plains	$ 14.00	$17.00	$21.50
TX, Southern Blacklands	$ 14.00	$21.00	$30.00
TX, South Rolling Plains	$ 14.00	$15.00	$16.50
Delta			
AR, Northeast	$ 23.00	$37.50	$43.50
AR, Southeast	$ 25.00	$38.50	$53.50
LA	$ 22.00	$38.50	$53.50
MS Delta	$ 20.00	$38.00	$53.50
MS Hills	$ 20.00	$38.00	$53.50
MO	$ 22.00	$24.00	$21.50
Southeast			
AL, Central	$ 22.50	$33.00	$46.00
AL, North	$ 22.50	$33.00	$46.00
AL, South	$ 22.50	$33.00	$46.00
FL	$ 22.50	$30.00	$59.50
GA	$ 21.00	$46.00	$61.50
NC	$ 19.50	$20.00	$33.00
SC	$ 25.00	$31.50	$33.00
TN	$ 12.00	$32.00	$48.00
VA	$ 20.00	$25.00	$33.00

Table 3. Bt cotton adoption: impacts on production, prices, and trade.

	1996	1997	1998
Increase in U.S. production (%)	0.6–1.8	0.8–2.1	1.1–2.9
Increase in U.S. exports (%)	1.5–4.3	1.7–4.6	2.7–7.2
U.S. farm price reduction (cents per pound)	0.5–1.4	0.6–1.4	0.8–2.1
Increase in commodity program payments (cents per pound)	0	0.6–1.6	0.8–2.0
Percent of production receiving program payments (%)	0	15	96

Table 4. Bt cotton adoption: producer, consumer, and budgetary impacts.

Change in:	1996	1997	1998
	(Million Dollars)		
Producer net returns	-1.6	20.0	88.4
Bt adopter net returns	57.5	69.0	96.8
Non-adopter net returns	-59.1	-49.0	-8.4
U.S. cotton purchaser benefits	45.9	45.2	55.3
Government payments	0.0	12.8	77.9
Net U.S. benefits	44.4	52.4	65.8
Rest of world net benefits	27.5	31.4	22.5
Foreign cotton purchaser benefits	327.5	339.4	400.0
Foreign cotton producer losses	-300.1	-308.0	-377.5
Total net benefits	71.8	83.8	88.2

Table 5. Regional impacts of Bt cotton adoption, 1998: moderate impact scenario.

Region	Net impact of Bt cotton adoption [a]	Bt cotton adopter gains	Non-adopter losses from lower cotton price
		(Million Dollars)	
Southwest	8.4	9.7	-1.3
AZ	8.6	8.7	-0.1
CA	-0.9	0.2	-1.2
NM	0.7	0.8	0.0
Southern Plains	-1.3	3.2	-4.6
OK	0.3	0.4	-0.1
TX	-1.6	2.8	-4.5
Delta	31.2	32.4	-1.2
AR	4.1	4.6	-0.5
LA	9.1	9.3	-0.2
MS	18.1	18.4	-0.3
MO	-0.1	0.0	-0.2
Southeast	50.1	51.5	-1.4
AL	9.5	9.6	-0.1
FL	0.7	0.7	0.0
GA	31.4	31.8	-0.4
NC	0.7	1.1	-0.4
SC	4.2	4.4	-0.1
TN	3.6	3.9	-0.2
VA	0.0	0.1	-0.1
Total	88.4	96.8	-8.4

[a]Numbers may not sum due to rounding.