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GLOBAL IMPACTS OF BT COTTON

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Abstract

This study combines a quadratic programming model of U.S. cotton production with a two-region trade model to estimate economic impacts of Bt cotton adoption in the United States and the Rest of World (ROW). Estimated global economic benefits of Bt cotton adoption were $580 million in 2001. U.S. producers captured $296 million of this gain, while U.S. cotton purchasers captured $40 million. Higher cotton production from Bt cotton adoption led to a 1.2 cent per pound reduction in the world cotton price. Commodity program payments sheltered U.S. producers from the effects of this price reduction. Lower prices resulted in significant gains for ROW cotton purchasers, but net losses for ROW producers, primarily those that did not adopt Bt cotton.

Introduction

In 2001, roughly 4 million hectares of cotton were planted to Bt cotton. This includes Bt-only varieties and stacked Bt and herbicide tolerant varieties. The United States still accounts for the bulk of world Bt cotton acreage at about 60 percent in 2001, with nearly 2.4 million hectares of Bt cotton (Williams). China planted nearly 1.5 million hectares (James; Huang 2002b) and Australia roughly 0.1 million hectares (CRDC). Smaller areas of Bt cotton were also planted in Argentina, Indonesia, Mexico and South Africa (Qaim and de Janvry (2002); James (2001); Ismael et al. (2002)). A growing body of literature reports that Bt cotton has led to significant yield gains, reductions in conventional insecticide sprays, or both in different regions throughout the world (Doyle et al., 2002; Frisvold and Tronstad (in press) Huang et al. 2002a, 2002b, 2002c; Ismael et al., 2002; Pray et al. 2001; Price et al., 2001; Qaim and de Janvry (2002); Traxler et al. (in press)). These studies examine adoption impacts in one region isolation of adoption impacts in others. Many assume that Bt cotton adoption has no impact on world or domestic cotton prices. This study combines an output price-endogenous quadratic programming model of U.S. cotton production with a two-region trade model to estimate economic impacts of Bt cotton adoption in the United States and the Rest of World (ROW). By doing so, the interactions between technological change and market prices can be examined.

Methods

A quadratic programming model of the U.S. and world cotton market discussed in detail in Frisvold and Tronstad (in press) was updated to 2001 data. The model includes 28 regions within the United States as well as a Rest of World (ROW) region to account for open economy impacts. The 28 regions correspond to those reported in the *Cotton Crop Loss* database (Williams, 2002), with the addition of a Southern California region. As typical of programming models, U.S. cotton supply is a step function, with steps representing marginal costs for Bt cotton adopters and non-adopters in each region. The step supply function is combined with linear 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 production, overall cotton demand, and demand for U.S. cotton exports. The average price received by U.S. farmers differs from the world price (Cotlook 'A' index 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. (1998), we adopt a baseline transmission elasticity of one. In the model as in reality, producers receive Loan Deficiency (POP) payments or market gain payments if the adjusted world price falls below the loan rate.

In the baseline model, U.S. acreage, yields, prices, program payment rates, exports and costs are calibrated to actual USDA data. ROW cotton production, consumption, demand for U.S. cotton exports and the world price of cotton are also set equal to USDA and cotton industry data. Implicitly, this data already accounts for the impacts of U.S. and ROW Bt cotton adoption. To estimate the impact of ROW adoption of Bt cotton, a supply shift parameter, z, is introduced into the ROW supply function:

$$Q_{RS} = a_{RS}\,(1+z) + b_{RS}\,P_w$$

where Q_{RS} is the quantity supplied by ROW, P_w is the world price and a_{RS} and b_{RS} are constants. Yield increases, cost reductions, or both from Bt cotton adoption are reflected in the size of z, which is set equal to zero in the model baseline. An increase in z from, for example, yield increases implies that more cotton will be supplied at any given market price.

To estimate the impact of Bt cotton adoption, we ask the counterfactual question, "what would the U.S. and ROW supply function look like if Bt cotton had not been adopted?" For the United States, the model is constrained so producers can only

grow conventional cotton. The impacts of U.S. Bt cotton adoption are measured by the differences between the baseline and constrained models. This approach is similar to previous quadratic programming analyses of pesticide cancellations (Deepak et. al., 1996; Sunding, 1996). If Bt cotton were not adopted in the ROW, the ROW supply function would shift upward in a parallel fashion (z becomes negative). This is similar to the approach used by Lichtenberg et al. (1988) to estimate impacts of pesticide cancellations. Through the market equilibrium equation, these shifts induce a shift in the equilibrium world price of cotton. One can then simulate how much higher the world price would have been had there been no U.S. or ROW Bt cotton adoption. We consider three impact scenarios: (1) Bt cotton adoption in the United States only, (2) adoption in the ROW only, and (3) adoption in both the United States and the ROW.

Data

U.S. regional and aggregate data sources used in the model are discussed in Frisvold et al. (2000) and Frisvold and Tronstad (in press). Estimates of domestic and export demand elasticities were based on Isengildina et al. (2000), Meyer (1999), Price et. al. (2001) and Sullivan (1989). ROW consumption, production, and demand for U.S. exports were derived from the Production Estimates & Crop Assessment Division of USDA's Foreign Agricultural Service and from various issues of the USDA Economic Research Service *Cotton and Wool: Situation and Outlook Yearbook*.

To estimate the impacts of Bt cotton adoption on U.S. producer yields and costs per acre, impact estimated were taken from a moderate impact scenario developed in Frisvold et al. (2000) and Frisvold and Tronstad (in press). Individual regional impacts were aggregated to obtain a national supply shift. To construct estimates of the z-shift parameter, we rely on information and data provided in Huang et al. (2002b) for China. In 2001, Bt cotton was also grown in Australia, Mexico, South Africa, Argentina, and Indonesia with the bulk of this in Australia. Combined, however, these countries accounted for such a small percent of ROW Bt cotton acreage relative to China that their impact on the z-shift parameter would be negligible. In Huang et al. (2002b), the reported yield advantage of Bt cotton was 5.82 percent nationally for China. Bt cotton accounted for 30 percent of total cotton acreage, while Chinese production accounted for slightly less than a third of ROW production. Therefore, the z-shift parameter was set at –0.0056 to estimate what the ROW supply curve would be without Bt cotton adoption.

Results

The three scenarios allow one to examine the global impacts of Bt cotton adoption in the United States only, ROW only, and the combined effects of adoption in both areas. Bt cotton increases cotton production and consumption and reduces world and U.S. prices. The effects are greatest with adoption in both areas, followed by adoption in the United States alone, then ROW alone. Because of Bt cotton adoption, U.S. production was 2.6 percent higher in 2001. With global adoption, the world price falls 1.2 cents per pound. While market prices fall, the effective price U.S. producers receive is maintained by loan deficiency payments (LDPs). This effective price equals the U.S. price received plus the LDP payment rate. In the model, world prices fall more than the average U.S. price received. Consequently, the payment rate increases more than the U.S. price received falls, so that the effective price U.S. producers receive actually increases.

U.S. exports rise 4 percent if adoption occurs only in the United States. With adoption also occurring in ROW, U.S. exports increase by only 3.7. If adoption occurred only in the ROW, U.S. exports would fall by –0.5 percent. With adoption in both areas, ROW production actually contracts (falling –0.1 percent). This occurs because the effect of lower world prices dominates the impacts of higher productivity growth in the ROW. This contraction would occur among Bt non-adopters in the ROW.

Total ROW benefits are the sum of ROW producer and consumer surplus, while total U.S. benefits are the sum of U.S. producer and consumer surplus, minus federal program payments (Table 2). The total economic surplus from Bt cotton adoption worldwide was $580 million in 2001. The U.S. captured 27 percent of this benefit with gains of $296 million, while the ROW captured 73 percent. First purchasers of cotton in the ROW are major beneficiaries of Bt cotton adoption with gains of $494 million. Producers in the ROW, primarily non-adopters of Bt cotton suffer losses of -$72 million. Bt cotton can increase yields and reduce pest control costs for adopters, but greater production in aggregate lowers market prices received by all producers. Non-adopters face only the price reduction effect.

Table 2 also highlights the consequences of falling behind technologically. If Bt cotton were adopted in the ROW, but not the United States, U.S. welfare would fall by -$18 million. If Bt cotton were adopted in the United States, but not the ROW, then ROW welfare would only increase by $27 million, while ROW producer returns would fall by -$262. Global adoption of Bt cotton reduces gains to the United States relative to the case where only the United States adopts. Global adoption of Bt cotton increases gains to the ROW relative to the case where only the ROW adopts. These results are consistent with those of Edwards and Freebairn (1984) who found that technological spillovers across regions reduce the gains from technological change in net exporting regions, while increasing the gains to net-importing regions. In the case of cotton, the United States is a net-exporter, while the ROW is a net-importer.

Discussion

The estimated benefits of Bt cotton from supply shifts in the United States and Rest of World (ROW) were $580 in 2001. These benefit estimates do not account for any additional environmental or worker safety benefits associated with reduced use of conventional insecticides. For more on this, see Edge, et al. (2001) Huang et al. (2002c) and Pray et al. (2001).

The results showing the costs of falling behind technologically also have implications for resistance management. The difference in U.S. benefits when both the US and ROW adopt Bt cotton and when only the ROW adopts may be interpreted as the cost of resistance to Bt developing in the United States. A similar comparison could be made to estimate the cost of "losing Bt" in the ROW.

An interesting extension of this present work would be to expand the regions modeled to the U.S., China, India and ROW. Bt cotton was first approved for use in India in 2002. Combined, the United States, China, and India account for about 55 percent of world cotton production. Earlier field trial results suggest that productivity gains in India from Bt cotton adoption could be substantial (Qaim, 2002). Some projections of adoption rates in China predict that Bt cotton's share of total cotton acreage will rise from 30 percent in 2001 to 79 percent by 2005 (Huang et al. 2002b). Large-scale adoption in India and China can have important implications for world cotton prices and trade patterns.

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Table 1. Impacts of Bt cotton adoption on prices, production, consumption and trade

	Impacts of Bt cotton adoption in:		
	U.S. only	**Rest of World (ROW) only**	**US & ROW**
Change in cents / lb.:			
World price	-0.7	-0.5	-1.2
US price received	-0.6	-0.4	-0.9
LDP payment rate	0.7	0.5	1.2
Effective US price	0.2	0.1	0.3
Change in levels (%):			
US production	2.6	0.0	2.6
US consumption	0.9	0.6	1.4
US exports	4.2	-0.5	3.7
ROW production	-0.3	0.2	-0.1
ROW consumption	0.2	0.1	0.4
ROW imports	4.2	-0.5	3.7

Table 2. Welfare impacts of Bt cotton adoption in the U.S. and the Rest of World (ROW)

	Impacts of Bt cotton adoption in:		
Change in ($ million)	**US only**	**ROW only**	**US & ROW**
US Welfare	177	-18	158
US Consumer Surplus	24	16	40
US Program Payments	133	44	178
US Producer Surplus	286	10	296
ROW Welfare	27	386	422
ROW Consumer Surplus	289	196	494
ROW Producer Surplus	-262	190	-72
Total Welfare	204	368	580