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IMPACTS OF BT COTTON ADOPTION IN THE UNITED STATES AND CHINA

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Abstract

This study uses a 3-region model to estimate the impacts of Bt cotton adoption in the United States and China on world price, returns to cotton purchasers, and returns to cotton purchasers in the U.S., China and the Rest of World. Combined adoption of Bt cotton in China and the United States increased world cotton production by 0.7 percent, but increased production reduced the world cotton price by 1.4 cents per pound. Net global economic benefits of adoption were nearly $900 million in 2001.

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. With nearly 2.4 million hectares of Bt cotton planted in 2001, the United States accounted for 60 percent of world Bt cotton acreage (Williams). China planted nearly 1.5 million hectares (James (2001); Huang 2002b) and Australia roughly 0.1 million hectares (CRDC, 2002). Smaller areas of Bt cotton were also planted in Argentina, Indonesia, Mexico and South Africa (Qaim and de Janvry (2003); 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 (CRDC (2002); Doyle et al. (2002); Frisvold and Tronstad (2002); Huang et al. (2002a), (2002b), (2002c); Ismael et al. (2002); Pray et al. (2001); Price et al. (2003); Qaim and de Janvry (2002); Qaim and Zilberman (2003); Traxler et al. (2002)). These studies examine adoption impacts in one region, in isolation of adoption impacts in others.

This study develops a three-region, output price endogenous model of the world cotton market to evaluate the global impacts of Bt cotton adoption in the United States and China in 2001. These two countries accounted for roughly 40 percent of world cotton production and over 95 percent of Bt cotton production in 2001. Although modest adoption occurred in the third, Rest of World region, on a world scale, these impacts would be small. In this study, the Rest of World (ROW) is affected by Bt cotton adoption via changes in the world price of cotton.

Methods

A quadratic programming model of U.S. cotton production was linked with a three-region model of the world cotton market. Frisvold and Tronstad (2002) discuss the programming model in detail. US values for that model were updated to 2001 data. The model includes 28 regions within the United States. 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, China supply and demand, and Rest of World (ROW) supply and demand. These four functions, combined with a net trade balance equation, determine the equilibrium world price of cotton, as well as ROW production, overall cotton demand, and demand for U.S. cotton exports. In 2001, the United States was a large net exporter of upland cotton, ROW was a large net importer, while China's net import levels were quite small, about one percent of consumption.

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 (LDP) payments or market gain payments if the adjusted world price falls below the loan rate. These payments act as a price support mechanism for U.S. producers. The difference between the Chinese farm price and the world price was modeled by a fixed price differential parameter.

In the baseline model, U.S. acreage, yields, prices, program payment rates, exports and costs are calibrated to actual USDA data. China and 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 Chinese Bt cotton adoption. To estimate the impact of China's adoption of Bt cotton, a supply shift parameter, z, is introduced into the supply function:

$$Q_{SC} = a_C (1+ z) + b_C P_C$$

where Q_{SC} is the quantity supplied by China, P_C is the farm gate price and a_C and b_C are constants. Yield increases and cost reductions 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 China supply function look like if Bt cotton had not been adopted?" For the United States, the programming 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 analyses of pesticide cancellations (Deepak et. al. (1996); Sunding (1996)). If Bt cotton were not adopted in China, the China 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 Chinese Bt cotton adoption. We consider three impact scenarios: (1) Bt cotton adoption in the United States only, (2) adoption in the China only, and (3) adoption in both the United States and the China.

Data

U.S. regional and aggregate data sources used in the model are discussed in Frisvold et al. (2000) and Frisvold and Tronstad (2002). Estimates of domestic and export demand elasticities were based on Isengildina et al. (2000), Meyer (1999), Price et. al. (2003) and Sullivan (1989). ROW consumption, production, and demand for U.S. exports were derived from the Production Estimates and 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 estimates were taken from a "moderate scenario" developed in Frisvold et al. (2000) and Frisvold and Tronstad (2002). Individual regional impacts were aggregated to obtain a national supply shift. Under this scenario, Bt cotton adoption reduced net pest control costs by $54 million as the increase in seed costs were outweighed by cost savings from reduced applications of conventional insecticides. U.S. cotton supply shifted out 2.7 percent.

To construct estimates of the z-shift parameter, we rely on information and data provided in Huang et al. (2002b) for China. Bt cotton accounted for 31 percent of total cotton acreage (Pray, et al., 2002). Several econometric studies have examined the farm-level impact of Bt cotton adoption on Chinese cotton production costs and yields (Pray et al. (2001), (2002); Huang et al. (2002a), (2002c)). Based on these studies, Huang et al. (2002b) reported a yield advantage of Bt cotton of 8.3 percent in Hebei, Henan, and Shandong provinces. These provinces accounted for 86 percent of Bt cotton acreage and 43 percent of all cotton acreage in China in 2001. The yield advantage in Anhui, Jiangsu, and Hubei provinces was 5.8 percent. These provinces accounted for 12 and 24 percent of Bt cotton and total cotton acreage. The reported yield advantage in the remainder of China was 3 percent. This area, accounted for a third of total cotton acres, but only 2.5 percent of Bt cotton acres. Based on these numbers, we assumed that Bt cotton adoption in China shifted supply in such a way to increase production 2 percent (at baseline price) and to reduce the marginal cost of production (at baseline quantity) by 24 percent. These assumptions appear in line with other studies (Huang et al. (2002b), (2002c); Pray et al. (2001)).

Impacts on Price, Production, Consumption and Trade

The three scenarios allow one to examine the global impacts of Bt cotton adoption in the United States only, China 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 China alone (Table 1).

In all scenarios, ROW increases consumption, reduces production, and increases its cotton imports, with the effects stronger with combined adoption. China's production increases (and imports decrease) the most if it is the sole adopter, but production declines (and imports increase) if the United States is the sole adopter. U.S. exports rise 4.3 percent if it is the sole adopter. With adoption also occurring in China, U.S. exports increase by only 3.6. If adoption occurred only in China, U.S. exports would fall by –0.7 percent.

Welfare Impacts

The change in economic welfare in ROW and China are measured as the sum of changes in producer and consumer surplus (Table 2). For the United States, the change in welfare is measured as the sum of the change in U.S. producer surplus, consumer surplus and innovator-monopolist rents charged to U.S. producers for seed, minus the change in US government program payments to cotton producers. Including innovator-monopolist rents follows in line with arguments put forth in Moschini and Lapan (1997). Ideally, one would also want to include measures of these rents captured in China. There, Bt seed varieties are supplied both by Monsanto / Delta and Pineland and the Chinese Academy of Agricultural Science (CAAS). At the time of writing, we did not have access to information about any profits captured in 2001. For 1999, however, Pray et al. (2001) report that Chinese suppliers just covered their costs, while Monsanto / Delta and Pineland received less than $2 million. Besides greater formal competition in the seed sector in China, farmers also save and re-plant Bt seed. Saved seed thus competes with new seed, exerting downward pressure on rents. Bt cotton acreage has roughly tripled in China from 1999 to 2001 (Huang et al. 2002b), however, so it would be interesting to include estimates of seed sales rents captured in future analysis.

The world economic surplus from Bt cotton adoption in the United States and China was $889 million in 2001. China captured 48 percent of this gain with $428 million to producers and $167 to consumers. ROW captured 8 percent of the gain, with consumer gains slightly exceeding producer losses. Losses to producers in ROW accrue because of the falling world price of cotton. US producers captured $232 million and consumers $48 million. US cotton program payments, however, increased by $198 million. US commodity program payments shelter U.S. producers from the impact of the falling world price, but at a budgetary cost. Increased program payments accounted for 86 percent of the US producer surplus gain. The United States as a whole captured 25 percent of the gain, with 16 of the 25 percent going to Monsanto / Delta and Pineland. Table 2 also highlights the consequences of falling behind technologically. If Bt cotton were adopted in the China but not the United States, U.S. welfare would fall by -$25 million. If Bt cotton were adopted in the United States, but not China, then welfare in China would only increase by $3 million, instead of $595 million with combined adoption. With only US adoption, producer surplus in China falls by -$84 million. Under joint adoption, ROW producers are worse off by $349 million. The costs of falling behind technologically have implications for pest resistance management. The difference in U.S. producer surplus when both the US and China adopt Bt cotton and when only China adopts may be interpreted as the cost to U.S. producers of resistance to Bt developing in the United States. A similar comparison could be made to estimate the cost of Bt resistance developing in China.

In simulation exercises, Edwards and Freebairn (1984) found that technological spillovers across regions reduce the gains from technological change in net exporting regions, while increasing the gains to net-importing regions. Our results are consistent with these earlier findings. In the case of cotton, the United States is a net-exporter, while the ROW and China are net-importers. US welfare is highest when it adopts alone, while welfare is highest for ROW and China when there is combined adoption.

Discussion

The estimated benefits of Bt cotton from supply shifts in the United States and Rest of World (ROW) were $889 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).

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. Field trial results suggest that productivity gains in India from Bt cotton adoption could be substantial (Qaim and Zilberman, 2003). 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 future world cotton prices and trade patterns.

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Table 1. Impact of Bt cotton adoption on cotton prices, production, consumption, and trade, 2001.

	Bt cotton adoption in:		
	US Only	**China Only**	**Both US and China**
	—Change in US cents per pound—		
World price	-0.7	-0.7	-1.4
US Loan Deficiency Payment rate	0.7	0.7	1.4
US farm price received	-0.6	-0.5	-1.1
	——— Percent change ———		
US consumption	0.9	0.8	1.7
US production	2.7	0.0	2.7
US exports	4.3	-0.7	3.6
China consumption	0.6	0.5	1.1
China production	-0.3	1.8	1.5
China imports[a]	60.2	-82.9	-22.7
ROW consumption	0.2	0.2	0.4
ROW production	-0.2	-0.2	-0.3
ROW imports	2.3	2.2	4.5
World cotton production	0.4	0.4	0.7

a. In 2001, net imports of upland cotton in China were small, about one percent of consumption. Large percentage changes represent small changes in import levels.

Table 2. World welfare effects of Bt cotton adoption in the US and China, 2001.

	Bt cotton adoption in:		
	US only	**China only**	**Both US and China**
	——$ millions, 2001——		
Rest of World (ROW)			
Change in consumer surplus	217	201	418
Change in producer surplus	-181	-168	-349
Change in welfare	36	33	69
China			
Change in consumer surplus	87	81	167
Change in producer surplus	-84	514	428
Change in welfare	3	594	595
United States			
Change in consumer surplus	25	23	48
Change in producer surplus	217	14	232
Change in government payments	134	63	198
Seed supplier US profits	143	0	143
Change in welfare	251	-25	224
Global Welfare	290	602	889