Economy-wide Impacts of Bt Cotton

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Abstract

This study uses a multi-region computable general equilibrium model to assess the impacts of international Bt cotton adoption on cotton and related sectors of regional economies. Productivity gain estimates are based on 2005 adoption rates for Bt cotton in seven countries. Global economic benefits are nearly $1.4 billion, while US benefits are over $200 million. Increased production from Bt cotton adoption leads to a 3% reduction in the world cotton price. Employment and trade balances in the textile and apparel sectors increase for China and India, but generally decline elsewhere. Individual countries obtain greater economic welfare gains if they adopt Bt cotton than if they do not adopt. Non-adopting regions lose cotton market share to adopting regions.

Introduction

In 2005, roughly 8.5 million hectares of cotton were planted to Bt cotton (James, 2005). This includes Bt-only varieties and stacked Bt and herbicide-tolerant varieties. A large body of literature reports that Bt cotton has led to significant yield gains, reductions in conventional insecticide sprays, or both throughout the world (Brookes and Barfoot; Frisvold et al.; Qaim and Matuschke).

Farm-level studies of Bt cotton impacts do not examine effects on world or domestic cotton prices. With rare exception, Bt cotton impact studies examine adoption in one region, in isolation of adoption in others. Studies that attempt to add up Bt cotton adoption impacts to a national or international level often do not account for the impacts of increased cotton production on price (Sankula and Blumenthal (2004); Brookes and Barfoot (2005).

Two exceptions to the fixed-price or single-region approaches are Falck-Zepeda et al. (2000), who considered a case where productivity gains in the United States were matched in the rest of the world (ROW) and Frisvold et al. (2006) who examined the effects of joint adoption in the United States and China in a three-region model that also included impacts on the ROW. Both studies explicitly account for price effects and are thus able to estimate benefits of adoption to cotton purchasers. The most comprehensive and ambitious study to date – by Elbehri and MacDonald (2004) – used a 15-region, 12-commodity computable general equilibrium (CGE) model to examine the potential impacts of Bt cotton adoption in West and Central Africa, given adoption in seven other regions. In that study, impact estimates were based on adoption rates in 2001.

The present study follows Elbehri and MacDonald's general approach, examining the impacts of Bt cotton adoption in a 9-region, 9-commodity CGE model. Bt cotton impacts are simulated based on higher, 2005 adoption rates and estimates of impacts on yields and costs in a number of regions based on more recent and larger-scale studies. The CGE framework allows us to examine, not only cotton sector impacts, but also trade, production, and employment impacts of global Bt cotton adoption in the textiles and apparel sectors.

GTAP model: commodity and regional aggregation

The economic effects of Bt cotton were quantified using the computable general equilibrium model of the global economy known as the GTAP (Global Trade Analysis Project) model (Hertel, 1997). We use the GTAP 6.0 database (Dimaranan and McDougall). The database disaggregates the world economy into 87 regions, 57 output sectors and five primary factors of production – unskilled labor, skilled labor, land, capital, and natural resources. It combines country-specific input-output data with detailed data for bilateral trade, transportation, tariffs, taxes, and subsidies.

For this study, the database is aggregated into 9 regions and 9 production sectors. There are seven Bt cotton-adopting regions (the United States, China, India, Australia, Argentina, Mexico, and South Africa) and two non-adopting regions (the European Union (EU), and the Rest of World (ROW)). There are three primary agricultural sectors – cotton, other crops, and animal production (livestock and dairy). The remaining six sectors are processed food products, textiles, apparel, chemicals, manufacturing, and services.

Productivity shocks

The impact of Bt cotton adoption is modeled as a factor-neutral productivity shock in the cotton sectors of the United States, China, India, Australia, Argentina, and Mexico, and a land-augmenting technical change for South Africa (explained below). Given the constant returns to scale assumption, the rate of technical change will equal the rate of cost diminution. Let Q = cotton produced, C/Q = unit cost, A = acreage, and Y = yield = Q/A, and C/A = cost per acre. Given constant returns to scale, a percent change in C/Q can be modeled as an equivalent factor neutral productivity change. Because $C/Q = (C/A)(1/Y)$ the change in C/Q can be decomposed into a change in yield and a change in cost per acre.

Empirical studies of farm-level or regional impacts of Bt cotton adoption often report estimates of the impact of Bt cotton on cost per acre (C/A) and yield (Y). Results from these studies, combined with estimates of national adoption rates, were used to construct weighted productivity shocks for each region adopting Bt cotton (Table 1). The shocks were based on 2005 adoption rates for each region. Adoption rates for the United States are based on the *Cotton Insect Losses* database (Williams, 2006). For other countries, estimates are based on James (2005) and on USDA Foreign Agricultural Service attaché reports known as Global Agriculture Information Network (GAIN) Reports. Productivity shocks for the United States were derived based on Frisvold et al. (2006) for China based on Huang et al. (2004), for Argentina based on Qaim and de Janvry (2003), for Mexico based on Gonzalez-García (2002), Magaña et al. (1999, 2002) and Traxler et al. (2002), and for Australia based on Fitt (2003).

Table 1. Estimated Total Factor Productivity Growth from Bt Cotton

	Percent Growth in Total Factor Productivity
Bt Cotton Adopting Regions	
USA	3.1
China	9.5
India	3.3
Australia	4.0
Mexico	7.5
Argentina	1.0
South Africa	3.2
Non-Adopting Regions	
EU	0.0
ROW	0.0

Calculating shocks for India is complicated by the large black market in unauthorized Bt cotton seed varieties. According to the USDA, Foreign Agricultural Service (Singh, 2006) 1.3 million hectares were planted to official varieties in 2005, while 1.2 million were planted to unofficial varieties. Unofficial plantings increased by 0.6 million hectares from 2004. Unofficial varieties sell at a lower price than authorized seed, but may have lower yields. Morse et al. (2005) compared costs and yields between official Bt hybrid varieties, non-Bt hybrid varieties and two unofficial varieties. One unofficial variety was first-generation seed after crossing two inbred lines, while the second was saved seed from the first unofficial variety. For the official varieties they found yield gains (over non-Bt cotton) in the 20%-37% range, comparable to other studies of Bt cotton in India. For the first unofficial variety, yield gains were less, 14% and there were no yield gains from the seed saved from this unofficial variety. To construct productivity shocks for official varieties, we used yield and cost estimates from Qaim et al. (2006), Bennett et al. (2004, 2006a). Productivity shocks for unofficial varieties were derived from Morse et al. (2005), where productivity gains were assumed only for the 0.6 million of new hectares planted to unofficial varieties in 2005. The overall productivity shock was based on a weighted average of estimated productivity gains from official and unofficial varieties.

For South Africa, we assumed land-augmenting technical change. Although cotton yields have increased substantially in South Africa in recent years, production has not increased because cotton acreage has declined. The land-augmenting technical change captures these two effects. Productivity gains here were based on estimates from Bennett et al. (2006b), Gouse et al. (2004), Ismael et al. (2002), and Thirtle et al. (2003). Productivity gains were weighted by acreage in small-scale dryland, commercial dryland, and commercial irrigated cotton acreage. Estimated productivity gains have been highest among small-scale, dryland producers, but commercial irrigated producers account for about 90% of cotton production.

Results

Cotton production increases in all Bt cotton adopting countries, except Argentina (Table 2). Percentage production increases are greatest in Australia and South Africa. Overall adoption in the United States is limited by low rates of adoption in the San Joaquin Valley of California and in the Texas High Plains. As cotton production in adopting countries increases, it declines in non-adopting regions. In China, textile production increases 1.2% and apparel production increases 0.6%, while in India, textile production increases 0.9% and apparel production increases 0.7%. In all other regions, except Argentina, textile and apparel production decline.

Table 2. Percentage Change in Production from Global Bt Cotton Adoption

	Cotton	Textiles	Apparel
Bt Cotton Adopting Regions			
USA	2.2	-0.1	-0.1
China	2.5	1.2	0.6
India	1.5	0.9	0.7
Australia	8.3	-0.5	-0.1
Mexico	5.8	-0.1	-0.1
Argentina	-0.5	0.1	0.0
South Africa	7.8	-0.3	-0.3
Non-Adopting Regions			
EU	-4.5	-0.5	-0.2
ROW	-2.2	-0.4	-0.1

Bt cotton has lead to a modest increase in world cotton production (0.35%) and more modest increases in world textile and apparel production (Table 3). Because of inelastic demand for cotton, the world price of cotton falls by about 3%. Prices of textiles and apparel also fell, but by much smaller percentages.

Table 3. Impact of Global Bt Cotton Adoption on World Prices and Production (percent change)

	World Price	World Production
Cotton	-3.09	0.35
Textiles	-0.20	0.07

Apparel	-0.07	<0.01

Global economic benefits of Bt cotton are on the order of $1.38 billion at 2005 adoption levels (Table 4). China captures 46% of this benefit, followed by the United States and India with 15% each. All regions in the model benefit from global Bt cotton adoption. The non-adopting Rest of World benefits by over $150 million and the EU benefits as well. US benefits are over $200 million.

Bt cotton adoption also shifts the balance of trade (Table 4). The cotton trade balance increases for all adopting countries except Argentina, while it deteriorates for non-adopting regions. The trade balances for textiles and apparel increase for China and India, but generally decline elsewhere. The decline is most pronounced in non-adopting regions.

Table 4. Impact of Bt Cotton Adoption on Economic Welfare and the Balance of Trade ($ US millions)

	Economic Welfare	Trade Balance		
		Cotton	Textiles	Apparel
Bt Cotton Adopting Regions				
USA	207.5	46.9	-89.3	-39.7
China	632.4	75.1	875.8	330.9
India	207.3	38.3	187.4	35.2
Australia	38.8	68.8	-4.8	-1.9
Mexico	65.9	37.1	-7.6	-19.5
Argentina	3.1	-2.9	1.0	-0.5
South Africa	3.0	2.4	-4.8	-0.9
Non-Adopting Regions				
EU	70.5	-32.4	-354.2	-117.9
ROW	151.8	-233.6	-609.9	-196.5
World Total	1,380.2			

Agricultural land rents – an indicator of returns to cotton producers – decline in all regions except Australia (Table 5). Employment in direct cotton production declines in all regions but Australia and South Africa. Textile and apparel employment increase in China, India, and Argentina, but it declines elsewhere.

Table 5. Percentage Change in Land Rents and Employment from Global Bt Cotton Adoption

Region	Agricultural Land Rents	Sector Employment		
		Cotton	Textiles	Apparel
USA	-0.1	-0.9	-0.1	-0.1
China	-0.2	-6.7	1.3	0.6
India	-0.3	-2.0	0.9	0.7
Australia	0.8	4.4	-0.5	-0.1
Mexico	-0.1	-1.7	-0.1	-0.1
Argentina	-0.1	-1.5	0.1	0.0

South Africa	-0.4	6.2	-0.3	-0.3
EU	-0.1	-4.6	-0.5	-0.2
ROW	-0.1	-2.3	-0.4	-0.1

We also compared the baseline adoption scenario with two hypothetical counter-examples (Table 6). In one case (the middle column) a simulation is run where adoption is assumed to occur only in the United States and China, with zero adoption rates in all other regions. In the second case (rightmost column) the US adoption rate is set equal to zero, while all other adopting countries have their baseline adoption rates. Both counter-examples illustrate that countries have lower welfare when they do not adopt Bt cotton. In all cases, a country's welfare is higher when it adopts. Non-adopting regions (EU and ROW) also have the largest welfare increases when global adoption is most widespread. Although the United States receives small gains from other countries adopting ($14.4 million), adoption of Bt cotton increases US welfare by an additional $193.1 million.

Table 6. Welfare Consequences of Not Adopting Bt Cotton

	All Regions but EU and ROW Adopt	Only US and China Adopt	US Does Not Adopt
	Welfare (measured as Equivalent Variation) ($US Millions)		
USA	207.5 [a]	214.8 [a]	14.4
China	632.4 [a]	642.9 [a]	634.1 [a]
India	207.3 [a]	-5.3	202.0 [a]
Australia	38.8 [a]	-1.4	47.3 [a]
Mexico	65.9 [a]	15.7	52.1 [a]
Argentina	3.1 [a]	-0.7	4.2 [a]
South Africa	3.0 [a]	1.7	3.1 [a]
EU	70.5	45.0	63.7
ROW	151.8	125.6	122.6
	1,380.2	1,038.2	1,143.2

Table 7 compares land rents and sector employment when other countries adopt and the US does or does not also adopt. In both cases U.S. agricultural land rents fall and employment declines in cotton, textile, and apparel production. However, the declines are larger if the United States does not adopt.

Table 7. Implications of US Non-Adoption of Bt Cotton for US Land Rents and Sector Employment

	Agricultural Land Rents	Sector Employment		
		Cotton	Textiles	Apparel
	% change	—— % change ——		
All Regions but EU and ROW Adopt	-0.13	-0.93	-0.11	-0.05
US Does Not Adopt	-1.16	-1.47	-0.20	-0.07

Discussion

Using a 9-region, 9-commodity computable general equilibrium (CGE) model we estimate that the global economic benefits of Bt cotton adoption in 2005 was nearly $1.4 billion. Gains to China were greater than $600 million, while gains to the United States and India were each greater than $200 billion. Fixed-cotton price estimates of Bt cotton impacts from previous studies report large gains to producers. However, increased production leads to a 3% decline in the world price of cotton. Agricultural land rents – a measure of returns to agricultural producers – decline in all regions except Australia. This suggests that major beneficiaries of Bt cotton are purchasers of cotton, who gain via lower prices.

Although global Bt cotton adoption leads to lower agricultural land rents and the movement of employment out of cotton, textile and apparel production. These negative effects in these sectors are even larger if the United States does not adopt Bt cotton. In general, individual countries obtain greater economic welfare gains if they adopt Bt cotton than if they do not adopt.

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