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Recent and Prospective Adoption of Genetically Modified Cotton: A Global CGE Analysis of Economic Impacts

Kym Anderson, Ernesto Valenzuela and Lee Ann Jackson

World Bank, Washington DC
kanderson@worldbank.org
evalenzuela1@worldbank.org

and

World Trade Organization, Geneva
Leeann.Jackson@wto.org

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Abstract

This paper provides estimates of the economic impact of initial adoption of genetically modified (GM) cotton and of its potential impacts beyond the few countries where it is currently common. Use is made of the latest version of the GTAP database and model. Our results suggest that by following the lead of China and South Africa, adoption of GM cotton varieties by other developing countries – especially in Sub-Saharan Africa – could provide even larger proportionate gains to farmer and national welfare than in those first-adopting countries. Furthermore, those estimated gains are shown to exceed those from a successful campaign under the WTO's Doha Development Agenda to reduce/remove cotton subsidies and import tariffs globally.

JEL codes: D58, F17, Q16, Q17

Key words: GMOs, cotton biotechnology, computable general equilibrium modeling, economic welfare, subsidy and tariff reform

Contact author:
Kym Anderson
Development Research Group
The World Bank
Mailstop MC3-303
1818 H Street NW
Washington DC 20433 USA
Phone +1 202 473 3387
Fax +1 202 522 1159
kanderson@worldbank.org

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1. Introduction

Cotton is important for many developing countries, either as a cash crop and/or as an input into their textile industry. It is receiving more attention of late for two reasons. One is because, thanks to genetic modification using modern biotechnology, new insect-resistant and herbicide-tolerant cotton varieties are emerging that are proving to be more productive than traditional varieties of cotton. Over the decade following their first release, genetically modified (GM) cotton rose to account for 28 percent of all land sown to cotton globally in 2005 and to one-ninth of the world's total area of GM crops. But the United States and China account for almost all of that, where the proportion of plantings that are GM are already more than four-fifths and two-thirds, respectively (Table 1).[1] The only other countries with high GM adoption rates by 2005 are Australia and South Africa, both with slightly more than four-fifths of their cotton areas under GM varieties. Apart from India and Mexico, where legal adoption began to take off only in 2003-04,

[1] China's adoption share is lower because insect infestations are low in the Western part of China where much of the crop is grown, so the gains from switching to current varieties of GM cotton are not yet sufficient to make the change. The drop in China's GM cotton acreage in 2005 (see Table 1) paralleled a drop in its non-GM cotton acreage as farmers moved away from land-intensive to labour-intensive crops.

and an unknown extent of (possibly illegal) plantings in Argentina, no other developing countries have widespread adoption yet of this new technology.[2]

The other reason cotton is in the news is because four poor cotton-exporting West African countries (Benin, Burkina Faso, Chad and Mali) have demanded that cotton subsidy and import tariff removal be part of the World Trade Organization's Doha Development Agenda. However, cotton subsidies are mostly provided by governments in high-income countries, and those governments have yet to be persuaded by other cotton-exporting countries to abandon them – notwithstanding the fact that part of the US cotton subsidy program has been ruled illegal following a WTO dispute settlement case brought by Brazil.

What is at stake here in terms of economic welfare in various developing countries? Specifically, how much are developing countries foregoing by procrastinating in their approval of GM cotton production? How does that compare with the effects on developing country and global welfare of removing cotton subsidies and import tariffs? And how much greater would be the gains to cotton-producing developing countries from GM cotton adoption if global cotton markets were not distorted by subsidies and tariffs?

After presenting a brief background to the world's cotton market in Section 2, this paper seeks to address these questions by using a well-received model of global economy known as GTAP (developed by Purdue University's Global Trade Analysis Project) and the latest version of its related trade and protection database, described in Section 3. Empirical simulation results are presented in Section 4. These are followed by a

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[2] Experimental work has begun in numerous other developing countries though, including in countries as poor as Burkina Faso. For a thorough review of such developments, see FAO (2004, Ch. 4).

discussion of caveats in Section 5. The concluding section summarizes the findings and draws policy implications for developing countries.

2. The global cotton market

Cotton production is highly concentrated in several respects. One is that most production is in a few countries: as of 2005/06, nearly half is produced by just China and the United States, and that rises to more than two-thirds when India and Pakistan are added and to more than three-quarters when Brazil and Ukbekistan are included. Also highly concentrated are exports of cotton lint, with the US, Australia, Uzbekistan and Brazil accounting for almost two-thirds of the world's exports, while the cotton-four in West Africa and the other four countries in Central Asia bring that total to almost four-fifths (Table 2).

Cotton usage, on the other hand, is distributed across countries roughly in proportion to their volumes of textile production. Because of high domestic usage by exporters of textiles and clothing in developing Asian countries (and Mexico because of its preferential access to the US and Canadian markets under NAFTA), even large cotton producers such as China, Pakistan and India export only a small fraction of their crop, in contrast to Sub-Saharan Africa and Central Asia where textile production is relatively minor. This explains the pattern of net exports of cotton and textiles across regions (columns 3 and 4 of Table 3), an understanding of which is helpful in explaining the signs of the welfare effects of some of the technology and policy shocks considered below.

3. The GTAP model and database

The standard Global Trade Analysis Project (GTAP) model of the global economy is used to provide insights into the effects of governments allowing GM technology adoption in some countries without and then with cotton trade and subsidy policy reform globally. See Hertel (1997) for comprehensive documentation of the GTAP model, which is a neo-classical multi-regional, static, applied general equilibrium model that assumes perfect competition, constant returns to scale and unchanging aggregate employment of all factors of production. We use the latest Version 6.05 of the GTAP database (see Dimaranan and McDougall, 2005), which draws on global economic structures, policies and trade flows of 2001. The GTAP model has been aggregated to depict the global economy as having 27 sectors and 38 regions (to highlight the main participants in the world's cotton markets, two of which are newly disaggregated countries: Nigeria and Pakistan). Trade is modeled using a nested Armington structure in which aggregate import demand for each sector's product is the outcome of allocating domestic absorption between domestic goods and aggregate imports, and then aggregate import demand is allocated across source countries to determine the bilateral trade flows.

This economy-wide GTAP model does not include environmental or human health externalities, so the welfare consequences of any such externalities are not measured. This unfortunate situation is a result of the uncertainty surrounding the relationships among various economic and environmental variables. What can be said, though, is that the net environmental effects of producing GM crops could be positive or negative – just as they could be for producing non-GM crops, which also are not captured in our model. On the one hand, many GM crop varieties have some attributes that are more environmentally friendly than their conventional non-GM counterparts. They also are less dangerous to farmers and the soil where they require reduced applications of pesticides. On the other hand, there is concern that some long-term and possibly irreversible negative environmental effects might occur in the future, although we are not aware of significant scientific evidence of such adverse effects.[3]

4. Model simulations and results of GM cotton adoption

To simulate the economic effect of adoption of GM cotton, we assume total factor productivity (TFP) in cotton production would rise by 5 percent in most adopting countries, net of any higher cost of GM seed.[4] This output-augmenting, Hicks-neutral TFP shock is a conservative estimate of the gain to farmers, according to experience to date (FAO 2004, Table 7; Marra, Pardey and Alston 2002; Qaim and Zilberman 2003; Huang et al. 2004) and bearing in mind that typically, in a small number of years after GM cotton adoption is allowed, more than four-fifths of production moves to GM varieties. In India and Sub-Saharan Africa other than South Africa, however, we assume a TFP shock of 15 percent. Even that higher value is conservative for those countries, according to Qaim and Zilberman (2003), because those countries' yields per hectare with conventional varieties are less than half the yields in the rest of the world (see last

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[3] Federoff and Brown (2004) give reasons why that null finding is not surprising from the viewpoint of a molecular biologist.

[4] In the GTAP database, cotton is part of a sector called 'plant-based fibers' but it represents well over 90 percent of the value of that sector. The only country for which this is likely to be of any significance is Bangladesh, which is still a large flax producer.

column of Table 2) and the GM field trials in India have been boosting yields by as much as 60 percent. More-recent commercial planting data suggest yield per hectare gains in India of more than one-third from adopting GM cotton varieties, and higher net profits despite the GM seed costing three times as much as non-GM seed (Qaim et al. 2006, Bennett et al. 2006).[5]

Three GM cotton adoption simulations are presented below. The first one aims to measure the market and welfare effects of adoption that had already taken place by 2001 in the United States, China, Australia, and South Africa. In China's case it was only about halfway through its adoption process as of 2001, so only a 2.5 percent TFP shock is applied in this case. The simulation is a negative one, in the sense that we examine how the world would have been had that 5 percent shock (2.5 percent in China's case) not taken place.

That first simulation is then compared with two other shocks: one in which all other countries except the rest of Sub-Saharan Africa adopt GM cotton (and China completes its adoption process), and the other in which Sub-Saharan Africa also adopts. The reason it is worth examining separately the impact of adoption by the rest of Sub-Saharan Africa is that the region has a history of very slow adoption of new agricultural technologies in the 1970s and 1980s, and during the 1990s its investments in agricultural R&D grew only 1 percent per year and spending actually fell in about half the countries for which data exist (Science Council 2005). To reiterate, the TFP shock in these latter two simulations is also 5 percent except for India and Sub-Saharan Africa (excluding South Africa) where it is 15 percent and for China where it is 2.5 percent. The potential

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[5] There are also benefits from insect-resistant Bt cotton in terms of improved health for farmers (see Hossain et al. 2004), and also less pesticide damage to soil and water, but these benefits are ignored in what follows.

net effect of this new biotechnology as of 2001 is thus the sum of effects from the first simulation (what had already taken place by 2001) and those from the third simulation (what still remained to be embraced after 2001).

First simulation (what had already taken place by 2001)

Results from the first simulation, presented in the final three columns of Table 3, suggest that world cotton output had hardly changed up to 2001. This is because the output gains in the first four GM-adopting countries were offset by output losses in the non-adopting countries, which were driven by the downward pressure on the average price of cotton in international markets (which fell by 2.5 percent as a result of this initial adoption, according to our model).[6] Globally, both value added by cotton farmers and the value of cotton exports were reduced by about 1 percent, and by more than that in most non-adopting regions. Note in particular that the largest changes in net income to cotton farmers are in Sub-Saharan Africa, with a rise in South Africa of 3.5 percent and a fall in the rest of Sub-Saharan Africa of 4.4 percent. Note also that among the GM cotton adopters, net incomes from cotton farming were lowered in both the United States and China, in part because of the decline in export prices. This is not to say individual farmers in those countries were irrational in adopting GM cotton, because had they not they would have still suffered from the product price fall, following adoption by other farmers, but would not have had a productivity improvement to partly offset it. For China, its small volume of cotton exports also was lowered, as most output is used by its domestic textile industry which expanded in response to the lower price of raw cotton.

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[6] That estimated price fall would have been somewhat less had we also included GM corn and soybean adoption at the same time, since that would have reduced the extent of diversion of resources to cotton.

The net economic welfare effects of this initial adoption of GM cotton are summarized in Table 4. For all four adopting countries this was positive despite the loss due to their terms of trade deterioration and, in all but Australia's case, a small loss from domestic resource reallocation to the cotton sector (the latter because resources are attracted from sectors that were less assisted by government policies than cotton). But notice also that welfare improves in all non-adopting regions but one. This is because they are net importers of cotton and so enjoy a terms of trade improvement. The exceptional non-adopting region is Sub-Saharan Africa (excluding South Africa) which as a net exporter of cotton faces lower cotton export prices and also has resources move to sectors in which it had a lesser comparative advantage. Globally, annual economic welfare was enhanced by more than $0.7 billion from this technology's adoption as of 2001, plus whatever net profits accrued to the biotech and seed firms.

Second and third simulations (technology catch-up)

If all other countries then adopt GM cotton, cotton output in the early-adopting countries falls in response to the output expansion in newly adopting regions. If Sub-Saharan Africa continues to procrastinate, its cotton output, value added and exports would fall even further; but if it also were to embrace this technology, its cotton industry would expand more than any other region's and would more than make up its losses to 2001 from adoption by the first four adopters (compare the final three columns of Tables 3 and 5). Note too that the value of global exports shrinks more in these two simulations than in the first one, indicating that more cotton would be grown in the regions where it is consumed the more developing countries adopt this technology.

Global welfare could be boosted very much more with greater adoption by developing countries. Even without Sub-Saharan Africa adopting, it would jump to $2.0 billion per year, even though that would lower slightly Sub-Saharan Africa's (and Australia's) welfare (Table 6). But adoption by the rest of Africa would raise that global benefit to $2.3 billion, with two-thirds of that extra $0.3 billion being enjoyed by Africa (more than offsetting its loss shown in Table 4 because of adoption by others up to 2001), and the rest by cotton-importing regions. Asia's developing countries that are net importers of cotton gain even if they grow little or no cotton, because the international price of that crucial input into their textile industry would be lowered further, by an average of 2.4 percent in this scenario (and as much as 4.1 percent when Sub-Saharan Africa also adopts, as compared with 2.5 percent from GM adoption by just the first four adopting countries). Note though that Australia's earlier gain would be erased by the fall in its cotton export price in this scenario. With complete catch-up as in this third scenario, the gains to Central Asia, Sub-Saharan Africa and South Asia are ten, thirteen and twenty-three times greater than the global gains when expressed as a percentage of regional GDP (Table 6b and Figure 1). South Asia's are especially large because it is a large producer of both cotton and textiles (Table 1).

Clearly, there are large benefits being foregone by developing countries that are procrastinating in their release of GM cotton varieties. It is gratifying to see that the governments of India and Mexico are now allowing growers access to them (see Table 1), and hopefully other governments will soon follow suit.

What if cotton subsidies and tariffs were removed?

How do the above prospective gains from adopting GM cotton compare with the effects of eliminating all cotton subsidies and tariffs, as called for by several African cotton-exporting countries as part of the WTO's Doha Development Agenda? And how much greater would be the developing countries' gains from GM cotton adoption if the world was free of cotton subsidies and tariffs?[7]

The extent of subsidies to cotton production and exports, and of tariffs on cotton imports, is non-trivial (see Anderson and Valenzuela 2006, Appendix Table A3). Large though some of the interventions are, the estimated global welfare gain from removing them ($283 million per year) is only one-eighth the above estimate of the gain from completing the adoption of GM cotton technology ($2.3 billion).[8] Furthermore, most of that protection cost is felt by the countries imposing those distortions. Indeed many developing countries – as net importers of cotton (see Table 3) – benefit from those subsidies and tariffs because they lower prices for cotton in international markets.

What is striking about the distribution of the welfare effects that would result from removing those distortions, however, is the relatively large benefit it would bestow on Sub-Saharan Africa. Indeed that potential gain of $147 million per year is almost as large as the region's estimated gain from joining with the rest of the world in embracing GM cotton technology. Such reform would boost the international price of cotton by an

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[7] The juxtaposing of gains from trade reform with gains from new technology adoption is uncommon among CGE modelers, but an early exception in the case of Africa is Hertel, Masters and Elbehri (1998).

[8] Of course if textile and clothing tariffs also were removed, global welfare would increase far more: by an extra $6.8 billion per year, according to our model's results.

average of 12.9 percent,[9] and lead to an estimated increase in Sub-Saharan African cotton output and value added of nearly one-third. The real value of cotton exports from Sub-Saharan Africa would increase by more than 50 percent, while cotton output and exports would fall by one-quarter in the United States and would halve in the EU (Table 7). That would raise Sub-Saharan Africa's share of global cotton exports from 12 to 17 percent, and the share of all developing countries from 52 to 72 percent.

Also striking is a comparison of the welfare result from cotton reform with that from removing *all* merchandise tariffs and agricultural subsidies. While the latter gain is nearly 300 times as great as the former globally, for Sub-Saharan Africa cotton reform is crucial: its potential contribution to the region's welfare of $147 million per year is one-fifth of the estimated $733 million gain for the region from the freeing of *all* goods markets globally.

If those distortions to cotton markets were removed, how different would be the estimated effects of further GM cotton adoption beyond that achieved by 2001? Globally it would be virtually no different, for reasons explained in Alston, Edwards and Freebairn (1988) and Anderson and Nielsen (2004). But the gains to developing countries in the absence of distortionary cotton policies would be slightly greater (12 percent so in the case of Sub-Saharan Africa), while those to high-income countries would be less (middle columns of Table 6).

Were these two reforms (GM catch-up and subsidy removal) to occur simultaneously, they would reinforce each other in Sub-Saharan Africa as each expands the region's cotton production and exports and so makes the gain from the other change

[9] This is close to the 10 percent estimated by Sumner (2006, p. 282), which is also the simple average of the studies surveyed by Baffes (2005, p. 122).

larger. This is evident in the final column of Table 8, which shows that the gain to Sub-Saharan Africa would then be ($223m + $147m =) $370m. This is equivalent to $199m + $172m, the former appearing in column 1 of Table 8 and the latter being the gain to Sub-Saharan Africa from global removal of cotton subsidies and tariffs had GM catch-up occurred before that reform. With these two reforms the average price of cotton in international markets would be 7.4 percent above the baseline, instead of 4.1 percent below as in the case of just GM catch-up alone. That is why the loss shown in Table 7 for South Asia following subsidy removal becomes a gain in the final column of Table 8 when that reform is accompanied by GM cotton adoption. Clearly this is an example of complementarity between the trade and development components of the Doha Cotton Initiative.

5. Caveats

We have ignored the owners of intellectual property in GM varieties, and simply assumed the productivity advantage of GM varieties is net of the higher cost of GM seeds. If that intellectual property is held by a firm in a country other than the GM-adopting country, then the gain from adoption is overstated in the adopting country and understated for the home countries of the relevant multinational biotech companies.

Also, we do not have enough knowledge of the potential positive and negative effects of GM varieties on the environment to incorporate them into our simulation model. As with food safety concerns, it would in any case not be sufficient to include them only for GM varieties; they would also need to be included for non-GM varieties to ensure even-handedness in the analysis. It happens that, prior to GM varieties, cotton farming in all but low-income countries has involved one of the most chemical-intensive forms of agricultural production. By switching to GM cotton, farmers have been able to lower substantially their applications of insecticides, thereby reducing soil, water and air pollution and improving the health of farmers and their neighbors. For cotton farmers in low-income countries (including much of India and Sub-Saharan Africa – see final column of Table 2), who have not yet had access to insecticides and other farm chemical and hence have relatively low yields and profits, GM cotton varieties offer an opportunity to leapfrog the chemical-intensive technology and provide a win-win-win for farm profits, human health, and the environment.

The technology shocks in our simulations assume a uniform increase in productivity of all factors and inputs used in GM cotton production. We use that assumption because it is simpler to describe, and it turns out there is little difference to the welfare results when we allow some factors to be saved more than others or some intermediate inputs such as pesticides to be needed less by GM crop varieties.

6. Conclusions

Adaptation and adoption of new genetically modified (GM) cotton varieties are within the powers of developing countries themselves. Unlike the Cotton Initiative in the WTO's Doha Development Agenda, governments in Sub-Saharan Africa and elsewhere do not need to wait until that round concludes to boost the incomes of their cotton farmers. Indeed the above results suggest that developing country welfare could be enhanced by more from allowing GM cotton adoption than by the removal of all cotton subsidies and tariffs.[10] Furthermore, our results support the notion that the gains to developing countries from the Doha Cotton Initiative will be even greater if GM cotton is adopted first, providing yet another reason not to delay approval of this new biotechnology.

Those developing countries with well-developed public agricultural research and extension systems (such as India) are well placed to benefit promptly from the new biotechnology by working in partnership or in parallel with private biotech and seed companies. Approving investments in those activities by the private sector – and the overall investment climate – will allow the process of adaptation and adoption to move forward. The experiences in China, India and South Africa all indicate that rapid and widespread adopt is then possible, including by small farmers. Many of Sub-Saharan Africa's low-income countries have poorly developed public agricultural research and extension public research agencies and unattractive investment climates though (Beintema and Stads 2004; Sithole-Niang, Cohen and Zambrano 2004; Cohen 2005). As those systems and associated intellectual property rights are improved, so the payoff from R&D spending to adapt appropriate local crop varieties will be enhanced. The potential benefits shown above from this new biotechnology should make that expenditure even more affordable now.

Moreover, the fear of adverse environmental or food safety issues have not been vindicated during the first decade of adoption by those countries and the US and Australia, not least because scientists and regulators have found ways to manage those

[10] There is no expectation that *all* cotton subsidies and tariffs will be removed as a result of the Doha round (see Sumner 2006 and Anderson and Valenzuela 2006), so the gains from GM adoption are even greater relative to prospective trade policy reform over the next decade.

risks. Indeed farmer, water and soil health have all improved thanks to the lesser pesticide needed with Bt varieties of GM cotton. Nor does GM cotton carry the stigma that GM food carries in high-income countries of Europe. If embracing GM cotton helps developing country governments to streamline also the process of approving the release of GM varieties of food crops (given the steady flow of scientific reports such as by King (2003) concluding that there is no evidence that GM foods are harmful either to the environment or to human or animal health), these economies would be able to multiply that $2 billion gain from GM cotton adoption by at least two, according to the numbers presented in Anderson and Jackson (2005) and Anderson, Jackson and Nielsen (2005).

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Table 1: Area of GM cotton and other GM crops, by country, 2002 to 2005

(million hectares)

(a) Total area

	2002	**2003**	**2004**	**2005**
United States	4.2	3.9	4.2	5.6
China	2.1	2.8	3.7	3.3
Australia	0.2	0.1	0.2	0.3
South Africa	0.0	0.0	0.02	0.03
India	0.0	0.1	0.5	1.3
Mexico	0.0	0.0	0.07	0.12
Total, cotton	**6.8**	**7.2**	**9.0**	**9.8**
TOTAL of all GM crops	**58.7**	**67.7**	**81.0**	**90.0**

(b) Area by product and variety, 2005

		Global GM area (m. ha)	Crop's share of global GM area (%)	Area under GM varieties as a % of crop's global area
Cotton:	Bt (insect resistant)	4.9	6	
	herbicide tolerant	1.3	2	
	Bt/herbicide tolerant	3.6	4	
	ALL COTTON	**9.8**	**11**	**28**
Soybean		54.4	60	60
Maize		21.2	24	14
Canola		4.6	5	18
TOTAL of four crops		**90.0**	**100**	**30**
TOTAL of all crops				**5**

Source: James (2005) and earlier issues.

Table 2: Volume of cotton[a] production, yield, trade and utilization, 2005-06

	Output (Kt)	Change in stocks (Kt)	Exports (Kt)	Imports (Kt)	Utilization (Kt)	Share of supply[b] exported (%)	National share of global output(%)	National share of global exports (%)	Yield per ha, % of global average
China	5819	9	10	2800	8600	0	23.5	0.1	163
United States	4735	408	3039	7	1296	70	19.1	37.5	122
India	4250	550	225	125	3600	6	17.1	2.8	63
Pakistan	2308	42	100	250	2415	4	9.3	1.2	103
Brazil	1191	-85	425	50	900	33	4.8	5.2	161
Uzbekistan	1100	14	837	1	250	77	4.4	10.3	110
Turkey	805	0	25	770	1550	3	3.2	0.3	181
Australia	496	-97	582		11	98	2.0	7.2	258
Greece	358	6	258	5	100	73	1.4	3.2	144
Syria	298	-9	150		158	49	1.2	1.9	192
Egypt	263	-8	125	75	220	46	1.1	1.5	137
Burkina Faso	254	-14	264		4	99	1.0	3.3	64
Mali	250	-1	247		4	98	1.0	3.0	68
Turkmenistan	219	6	114		100	54	0.9	1.4	52
Tajikistan	162	6	132		25	85	0.7	1.6	80
Argentina	155	-5	50	20	130	31	0.6	0.6	63
Mexico	152	-33	45	287	428	24	0.6	0.6	169
Kazakhstan	147	5	134	5	12	94	0.6	1.7	99
Benin	140	-49	186		3	98	0.6	2.3	67
Côte d'Ivoire	124	11	103		10	91	0.5	1.3	62
Iran	120	0	10	10	120	8	0.5	0.1	114
Cameroon	112	-78	57	1	132	30	0.5	0.7	69
Spain	110	0	63	15	62	57	0.4	0.8	178
Sudan	96	0	92		4	96	0.4	1.1	67
Tanzania	96	-24	104		16	87	0.4	1.3	31
Paraguay	90	42	43		5	90	0.4	0.5	49
Nigeria	87	2	30	15	70	35	0.4	0.4	33
Zambia	76	0	55		20	72	0.3	0.7	39
Chad	72	-5	77		1	100	0.3	0.9	33
Zimbabwe	72	-13	58		26	68	0.3	0.7	36
Peru	70	1	2	23	90	3	0.3	0.0	118
Togo	70	-9	79		0	100	0.3	1.0	54
Myanmar	59	0	11		47	19	0.2	0.1	29
Colombia	55	21		78	111	0	0.2	0.0	109
Azerbaijan	55	5	41		8	82	0.2	0.5	71
Kyrgyzstan	38	0	39	3	3	103	0.2	0.5	121
Uganda	37	-5	38		4	90	0.1	0.5	52
Mozambique	25	-3	26		2	93	0.1	0.3	16
Ethiopia	22	0	2		20	9	0.1	0.0	38
South Africa	21	0		39	60	0	0.1	0.0	73

Source: ICAC (2005).

[a] Cotton, refers to ginned lint or raw cotton. It does not include seed cotton, linters, cotton mill waste, or cotton fibers subjected to any processing other than separation of lint from seed by the gin. Annual data are for the cotton year beginning 1 August. [b] Supply is output plus change in stocks.

Table 3: Global market shares and net exports of cotton, and effects of GM cotton adoption as of 2001 on cotton output and exports, 2001

	Share (% by value) of global cotton:		*Net exports[a] ($b) of:*		% change from GM cotton adoption in:		
	output	*exports*	*cotton*	*textiles and clothing*	cotton output volume	value of cotton exports	value added in cotton prod'n
Adopters as of 2001:							
United States	*18*	*27*	*2.2*	*-60.7*	4.8	4.4	-0.1
China	*17*	*1*	*-0.1*	*41.9*	0.4	-4.3	-1.6
Australia	*3*	*13*	*1.1*	*-2.6*	7.2	4.3	2.1
South Africa	*0.1*	*0.3*	*-0.0*	*-0.2*	8.1	4.3	3.5
Non-adopters as of 2001:							
Other high-income countries	*5*	*13*	*-1.7*	*-28.4*	-3.5	-5.7	-3.2
Eastern Europe and Central Asia	*16*	*18*	*0.2*	*7.4*	-1.0	-4.5	-0.8
Southeast Asia	*1*	*1*	*-1.5*	*18.4*	-2.3	-8.4	-1.4
South Asia	*21*	*3*	*-1.0*	*24.5*	-1.0	-8.8	-0.6
Middle East and North Africa	*8*	*7*	*0.3*	*-3.3*	-1.6	-7.8	-1.5
Sub-Saharan Africa (excl S. Africa)	*5*	*13*	*1.1*	*-1.5*	-4.6	-7.5	-4.4
Latin America and Carib.	*6*	*4*	*-0.5*	*4.9*	-2.5	-8.9	-2.1
World	***100***	***100***	***0.0***	***0.0***	**0.2**	**-1.1**	**-1.0**

[a] Exports minus imports, both valued at f.o.b. prices as in the GTAP database 6.05

Source: Authors' GTAP model simulation results and (for columns 1 to 4) the GTAP database

Table 4: Effects of GM cotton adoption on national economic welfare as of 2001

(equivalent variation in income, 2001 US$m)

	Welfare changes due to effects of:			Total welfare change
Adopters as of 2001:	resource re-allocation	new technology	terms of trade change	
United States	-47	485	-114	324
China	-18	214	-34	162
Australia	2	63	-39	26
South Africa	-1	2	1	2
Non-adopters as of 2001:				
Other high-income countries	46	0	101	147
Eastern Europe and Central Asia	0	0	5	5
Southeast Asia	-15	0	51	36
South Asia	4	0	10	14
Middle East and North Africa	5	0	9	14
Sub-Saharan Africa (excl S. Africa)	-4	0	-13	-17
Latin America and Carib.	7	0	22	29
World	-22	764	0	742

Source: Authors' GTAP model simulation results

Table 5: Prospective effects of GM cotton adoption by non-adopters as of 2001 on cotton output and exports, without and with Sub-Saharan Africa participating

(percent change from baseline)

	Without Sub-Saharan Africa adopting, % change in:			*With* Sub-Saharan Africa adopting, % change in:		
First adopters as of 2001:	cotton output volume	value of cotton exports	value added in cotton prod'n	cotton output volume	value of cotton exports	value added in cotton prod'n
United States	-3.8	-9.5	-2.7	-5.4	-13.7	-3.9
China	0.2	-0.9	-1.7	-0.1	-8.4	-1.9
Australia	-6.1	-8.2	-5.6	-10.1	-13.5	-9.3
South Africa	-4.7	-7.5	-5.0	-13.7	-14.4	-14.7
New and prospective adopters:						
Other high-income countries	5.0	0.9	0.0	0.5	-5.9	-4.0
Eastern Europe and Central Asia	2.0	0.3	-2.3	0.6	-6.4	-3.1
Southeast Asia	0.4	-0.3	-1.6	0.0	-6.3	-1.9
South Asia	6.2	10.4	-2.9	5.6	3.1	-3.2
Middle East and North Africa	2.1	1.3	-2.7	0.2	-6.4	-4.5
Sub-Saharan Africa (ex S. Africa)	-7.4	-11.8	-7.2	26.7	22.2	10.0
Latin America and Carib.	3.0	2.0	-1.7	1.1	-6.4	-3.4
World	**1.0**	**-5.3**	**-2.7**	**1.0**	**-6.2**	**-2.9**

Source: Authors' GTAP model simulation results

Table 6: Prospective effects of GM cotton adoption by non-adopters as of 2001 on national economic welfare, without and with Sub-Saharan Africa participating
(equivalent variation in income, 2001 US$m)

(a) *Without* Sub-Saharan Africa adopting

	Welfare changes due to effects of:			Total welfare change	
First adopters as of 2001:	resource re-allocation	new technology	terms of trade change	in US$m	as % of GDP
United States	106	0	-45	61	0.001
China	-13	204	-78	113	0.010
Australia	1	0	-15	-14	-0.004
South Africa	1	0	4	5	0.004
New and prospective adopters:					
Other high-income countries	54	93	124	271	0.002
Eastern Europe and Central Asia	3	323	-1	325	0.049
Southeast Asia	-1	26	6	31	0.008
South Asia	75	880	9	964	0.157
Middle East and North Africa	10	133	14	157	0.018
Sub-Saharan Africa (ex S. Africa)	-4	0	-14	-18	-0.009
Latin America and Carib.	12	116	-4	124	0.006
World	**244**	**1775**	**0**	**2018**	**0.006**

(b) *With* Sub-Saharan Africa adopting

	Welfare changes due to effects of:			Total welfare change	
First adopters as of 2001:	resource re-allocation	new technology	terms of trade change	in US$m	as % of GDP
United States	139	0	-83	57	0.001
China	-14	204	-90	100	0.009
Australia	0	0	-28	-28	-0.008
South Africa	1	0	11	12	0.010
New and prospective adopters:					
Other high-income countries	82	91	165	337	0.003
Eastern Europe and Central Asia	0	321	-5	317	0.048
Southeast Asia	-11	25	49	63	0.009
South Asia	80	877	13	970	0.158
Middle East and North Africa	14	132	28	175	0.020
Sub-Saharan Africa (ex S. Africa)	36	221	-69	187	0.091
Latin America and Carib.	12	115	9	135	0.007
World	**338**	**1985**	**0**	**2323**	**0.007**

Source: Authors' GTAP model simulation results

Table 7: Impact of removing cotton subsidies and tariffs[a] on cotton output, exports and value added, and on national economic welfare

(percent and 2001 US$m)

	Change in cotton output volume (%)	Change in cotton value added (%)	Change in value of cotton exports (%)	Welfare changes ($m) due to effects of:		
				resource re-allocation	terms of trade change	TOTAL
All high-income countries	**-20.4**	**-15.4**	**-18.2**	**187**	**275**	**462**
Australia	25.0	22.2	38.1	12	125	137
United States	-24.6	-17.9	-29.0	-15	443	428
EU25	-54.0	-53.3	-48.8	124	-109	15
Japan	0.7	1.5	61.9	25	-49	-24
Korea-Taiwan	11.9	6.9	33.6	21	-84	-63
Other High income	**-36.1**	**-36.6**	**-41.7**	**190**	**-293**	**-103**
All developing countries	**5.7**	**4.3**	**46.3**	**96**	**-275**	**-179**
E. Europe and Central Asia	7.0	3.3	35.9	21	-36	-15
China	2.0	1.5	75.7	5	45	50
Other East Asia	8.7	5.1	65.3	39	-82	-33
India	-0.6	-0.4	31.1	-5	-79	-84
Other South Asia	6.0	3.5	59.8	9	-20	-11
Middle East & North Africa	6.2	6.1	37.4	-7	26	19
South Africa	19.4	20.6	46.5	2	-2	0
Other Sub-Saharan Africa	32.1	30.6	55.0	32	115	147
Argentina	13.6	10.7	66.1	1	6	7
Brazil	9.8	10.3	57.6	1	12	13
Mexico	13.0	10.5	42.3	11	-136	-125
Other Latin American & Car.	9.4	7.3	44.7	-13	-34	-47
World	**-0.8**	**-1.8**	**7.9**	**283**	**0**	**283**

[a] Removal of those distortions left after the eventual phase-out of the quotas under the Multifibre Agreement at the end of 2004.

Source: Authors' GTAP model simulation results

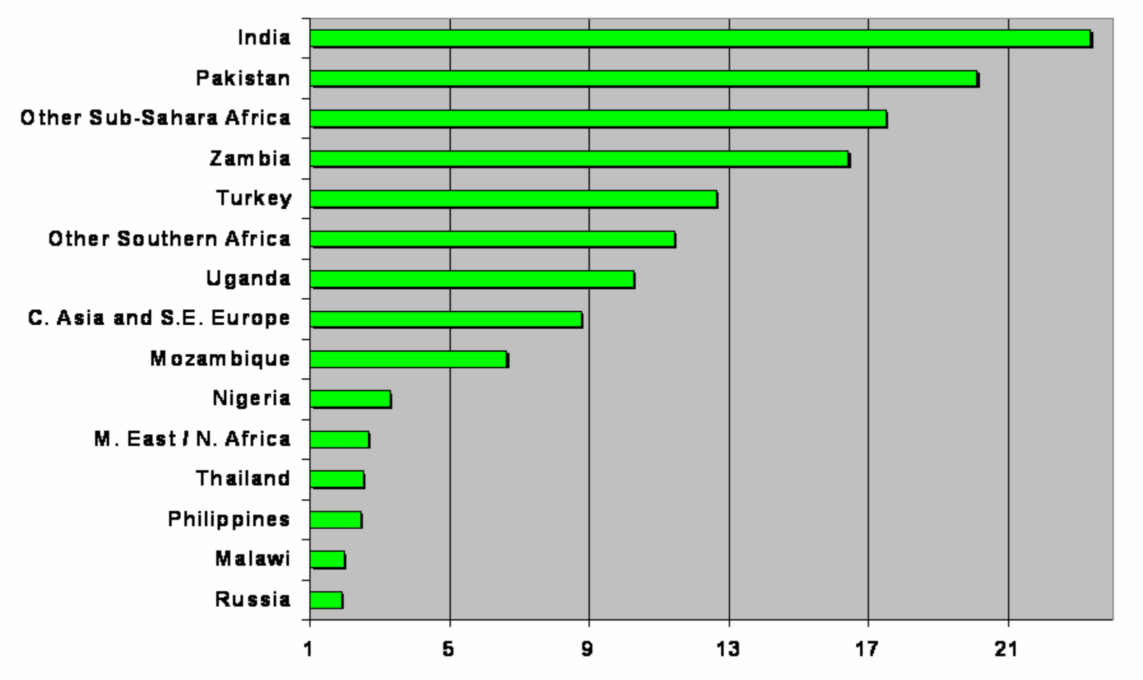
Table 8: Prospective effects of GM cotton adoption by non-adopters as of 2001 on national economic welfare, without and with cotton subsidies and tariffs removed first

(equivalent variation in income, 2001 US$m)

	Without subsidy and tariff reform	With cotton subsidies and tariffs first removed	With simultaneous cotton subsidy/tariff removal and GM catch-up
All high-income countries	366	279	744
Australia	-28	-58	80
United States	57	-25	404
EU25	269	281	295
Japan	36	37	14
Korea-Taiwan	-14	-6	-68
All developing countries	1957	2043	1866
E. Europe and Central Asia	317	317	303
China	100	94	144
Other Southeast Asia	63	83	-48
India	822	855	771
Other South Asia	148	151	140
Middle East & Nth Africa	175	211	194
Sub-Saharan Africa	199	223	370
Latin American & Carib.	135	146	-8
World	**2323**	**2322**	**2610**

Source: Authors' GTAP model simulation results

Figure 1: Welfare gain from GM cotton adoption as a percent of GDP, as a multiple of the percentage gain to the world as a whole



Source: Authors' GTAP model simulation results