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Abstract

China, GMOs, and world trade in agricultural and textile products

China has always strived for self-sufficiency in farm products, particularly staple foods. Its rapid industrialization following its opening up to global markets during the past two decades has been making that more difficult, and its accession to the WTO may add to that difficulty. New agricultural biotechnologies could ease that situation. However, the adoption and spread of some of those biotechnologies in agriculture have raised concerns, particularly over the environmental and food safety effects of genetically modified organisms (GMOs). This paper focuses on possible implications of the GMO controversy for China, since it is prospectively not only a major producer and consumer of GM farm products but also a potential exporter of some of them. It explores the potential economic effects of China not adopting versus adopting GMOs when some of its trading partners adopt that technology. The effects are shown to depend to a considerable extent on the trade policy stance taken in high-income countries opposed to GMOs and/or to liberalization of China's trade in textiles and apparel.

Key words: GMOs, trade policy, import ban, China, WTO

JEL codes: C68, D58, F13, O3, Q17, Q18

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1. Introduction

The use of modern biotechnology to create genetically modified organisms (GMOs) through agricultural research has generated exuberance by those looking forward to a new ‘green revolution’. In China especially, biotechnology is seen as a way of boosting the country’s food security via greater self-sufficiency, offsetting the forces of industrialization that tend to draw mobile resources from agriculture over time and that may exacerbate following China’s accession to the World Trade Organization (WTO). For that reason, and to avoid becoming dependent on imported biotechnology, China has been investing heavily in biotech research since the mid-1980s (Huang, Wang and Zhang 2001). By 2000 it had the fourth largest area sown to GM crops, after the United States, Argentina and Canada (James 2001).

But GMOs have also attracted strong criticism. The opposition is coming from groups concerned about the safety of consuming genetically modified foods, the environmental impact of growing genetically engineered plants, and the ethics related to using that technology *per se*. Scepticism toward genetic engineering has been particularly rife in Western Europe, but questions about the need at least for labelling GM-inclusive foods are also being raised in numerous Asian economies. Some (e.g. Sri Lanka) have taken the extreme step of banning the importation of GM products, and Japan and Korea are also introducing restrictive laws. In contrast, farmers in North America and several large developing countries are adopting GM crops, and citizens there have generally (perhaps unwittingly) accepted that development.

The worries being expressed abroad about GMOs concern the Chinese Government, and not just because its own citizens may thereby become wary of consuming GM products. Also important are issues of market access for China’s food exports. Britain is reported to have banned the importation of Chinese soy sauce in 2000 because the soybeans it was produced from may have contained GMOs (as they had been imported from the US). According to a recent newspaper report (O’Neill 2001), that action has prompted the Chinese Government to ban for the moment the growth of genetically modified rice, wheat, corn and soybean. Policy makers in China whose job is to decide how much to keep investing in biotech research therefore have even more uncertainty to contend with in the case of GM products.

Environmental, food safety and ethical concerns with the production and use of GM crops have been voiced so effectively as to lead to the recent negotiation of a Cartagena Protocol on Biosafety (UNEP 2000) with its endorsement of the use of the precautionary principle. However, if that Protocol were to encourage discriminatory trade barriers or import bans, or even just long delays in approving the use of imported GM seeds, it may be at odds with countries’ obligations under the WTO. The differences in attitudes toward

GMOs among major WTO members could therefore become a source of trade disputes in the WTO (as it could have between Britain and China in 2000, had China been a WTO member then). This is casting a shadow over the prospects for liberalization of world trade in farm products in the next WTO round of multilateral trade negotiations (Anderson and Nielsen 2001). It has also contributed to the slowing of growth in the area planted to GM crops globally: in 1999 it grew 12 million hectares, but in 2000 the area expanded by only 4 more million hectares to 44 million. Even more telling was the distribution of that growth in 2000: almost none of it was in the advanced industrial countries where negative consumer attitudes have been strongest (James 2001).

What are the implications of the GMO controversy for China, a pending WTO member? Since it is prospectively not only a major producer and consumer of GM farm products but also an exporter of some of them, it has to weigh the various environmental, health, and market access risks associated with adopting GM technology against the food, feed and fibre security and other benefits associated with producing or importing that technology.

The next section of the paper quantifies the potential economic effects of China not adopting versus adopting GMOs when some of its trading partners adopt that technology. This is done using the computable general equilibrium model of the global economy known as GTAP, which is projected forward to 2005 by which time it is assumed China is in the process of implementing its WTO accession commitments and the Uruguay around trade liberalization has been finished as scheduled. The results focus on four GM crops: rice, cotton, corn, and soybean. The effects are shown to depend to a considerable extent on the trade policy stance taken in high-income countries opposed to GMOs and/or to the liberalization of China's trade in textiles and apparel following China's accession to the WTO. Some tentative implications for China are drawn out in the final section.

2. **Quantifying the impact on China of GMOs**

Theory alone is incapable of determining even the likely direction, let alone the magnitude, of some of the effects of subsets of the world's farmers adopting GM-inclusive seeds. Hence an empirical modelling approach is called for. To illustrate the usefulness of that approach in informing GMO debates, this section summarizes one recent quantitative effort by the authors. It makes use of a well-received empirical model of the global economy (the GTAP model) to examine what the effects of some countries adopting the new GMO technology without and then with China also adopting. Specifically, the effects of an assumed degree of GM-induced productivity growth in selected countries are explored for rice, cotton, maize, and soybean.[1]

Being a general equilibrium model, GTAP (Global Trade Analysis Project) describes both the vertical and horizontal linkages between all product markets both within the model's individual countries and regions as well as between countries and regions via their bilateral trade flows. The database used for these applications draws on the global economic structures and trade flows of 1995, which have been projected to 2005.

[1] Maize and soybean are perhaps the most controversial because they are grown extensively in rich countries and are consumed by people there both directly and via animal products. Much less controversial to date are cotton (because it is not a food) and rice (because it is mostly consumed in developing countries).

We conduct our analysis on the projected database for the year of 2005 due to the fact that the GM technology is still at the early and experimental stage and it takes years for it to be adopted commercially on a large scale. That projection follows earlier similar modelling work by Anderson et al. (2000) in that it assumes the Uruguay Round commitments of WTO members are fully implemented by 2005. In addition, in the present study we assume China's commitments to open up as part of its negotiations to accede to WTO are mostly implemented by 2005, the exception being textiles and apparel which are to be subject to safeguards until 2008 following the removal of VERs at the end of 2004. The projection of the world's national economies is based on the World Bank estimates cited in Anderson et al. (1997) and Walmsley and Hertel (2000). This base projection from 1995 to 2005 assumes no agricultural biotechnology adoption, and is to be compared with alternative projections which assume a subset of countries adopt GM crops. To make the results easier to digest, the GTAP model has been aggregated to depict the global economy as having 16 regions (to highlight the main participants in the GMO debate), and 17 sectors (with the focus on the primary agricultural sectors affected by the GMO debate and their related processing industries). The base data as projected to 2005 are shown in Appendix Tables A1 to A3 (with the regional definition shown in Table A4).[2]

The scenarios analysed here assume that GM-driven productivity growth occurs only in the following GTAP sectors and for a subset of countries: paddy rice, plant fibres (primarily cotton in the countries considered), coarse grain (primarily maize in the countries considered), and oilseeds (primarily soybean in the countries considered). Detailed empirical information about the impact of GMO technology in terms of reduced chemical use, higher yields and other agronomic improvements is at this stage quite limited (see e.g. OECD (1999) and Nelson et al. (1999)). Available empirical evidence (e.g. USDA 1999 and James 2001) does, however, suggest that cultivating GM crops has general cost-reducing effects.[3] The following scenarios therefore are based on a simplifying assumption that the effect of adopting GM crops can be captured by a Hicks-neutral technology shift, i.e. a uniform reduction in all primary factors and intermediate inputs to obtain the same level of production. For present purposes the GM-adopting sectors are assumed to experience a one-off increase in total factor productivity of 5%, thus lowering the supply price of the GM crop to that extent.[4] Assuming sufficiently

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2 The GTAP (Global Trade Analysis Project) model is a multi-regional, static, applied general equilibrium model based on neo-classical microeconomic theory with international trade described by an Armington (1969) specification (which means that products are differentiated by country of origin). See Hertel (1997) for comprehensive model documentation and McDougall et al. (1998) for the latest GTAP database.

3 Nelson et al. (1999), for example, suggest that glyphosate-resistant soybeans may generate a total production cost reduction of 5%, and their scenarios have *Bt* corn increasing yields by between 1.8% and 8.1%. *Bt* cotton in China has lowered the cash and labour costs of production (i.e., ignoring land and water costs) by between one-fifth and one-third (Pray et al. 2001).

4 Due to the absence of sufficiently detailed empirical data on the agronomic and hence economic impact of cultivating GM crops, the 5% productivity shock applied here represents an average shock (over all specified commodities and regions). Changing this shock (e.g. doubling it to 10%) generates near-linear changes (i.e. roughly a doubling) in the effects on prices and quantities. This lowering of the supply price of GM crops is net of the technology fee paid to the seed supplier (which is assumed to be a payment for past sunk costs of research) and of any mandatory 'may contain GMOs' labeling and identity preservation costs. The latter are ignored in the CGE analysis to follow, but further research might explicitly include them and, to fine-tune the welfare calculations, even keep track of which country is the home of the (typically multinational) firm receiving the technology fee. The mergers and

elastic demand conditions, the cost-reducing technology will lead to increased production and higher returns to the factors of production employed in the GM-adopting sector. Labour, capital and land consequently will be drawn into the affected sector. As suppliers of inputs and buyers of agricultural products, other sectors will also be affected by the use of genetic engineering in GM-potential sectors through vertical linkages. Input suppliers will initially experience lower demand because the production process in the GM sector has become more efficient. To the extent that the production of GM crops increases, however, the demand for inputs by producers of those crops may actually rise despite the input-reducing technology. Demanders of primary agricultural products such as maize and soybean meal for livestock feed will benefit from lower input prices, which in turn will affect the market competitiveness of livestock products. The same is true for textile producers able to buy cheaper cotton.

The widespread adoption of GM varieties in certain regions will affect international trade flows depending on how traded is the crop in question. To the extent that trade is not further restricted and not currently subject to binding quantitative restrictions, world market prices for these products will have a tendency to decline and thus benefit regions that are net importers of these products. For exporters, the lower price may or may not boost their trade in value term, depending on price elasticities in foreign markets. Welfare in the exporting countries would go down for non-adopters but could also go down for some adopters if the adverse terms of trade change were to be sufficiently strong. Hence the need for empirical analysis, particularly when the country in focus, as in China's case, is a large global player in some of the markets affected.

In order to appreciate the projected relative importance of these primary and processed agricultural sectors in global markets by 2005, details are provided in Appendix Tables A1 to A3 for all regions. Shares of production, consumption, exports and imports are presented, along with the various regions' net trading situations in raw and processed forms as summarized in the self-sufficiency ratio. In Table 1 we summarize those observations just for China in 2005. Also shown in Table 1 are the actual self-sufficiency ratios as of 1995. They reveal that during the decade to 2005 China's self-sufficiency in agricultural products is expected to fall from 98.8% to 97.2% in the course of China's economic growth and accession to WTO as the rest of the world continues to grow and completes its adoption of Uruguay Round commitments.

Scenario 1: Selected countries including China adopt GM rice[5]

China is virtually self-sufficient in rice, and is expected to change little by 2005 in the absense of new technologies at home or abroad. Given that without GM rice technology China is projected by 2005 to be producing and using just over one-quarter of the world's rice (Table 1), its decision as to whether to embrace GM technology for rice can be expected to have a big impact, via the terms of trade, on the economy not only of China but also of other rice-dominant economies. To get a sense of how large that might be, we compare the impact of GM-driven productivity growth of 5 per cent in rice production in North America, the Southern Cone of South America (Argentina, Chile and Uruguay)

acquisitions among life science firms in recent years, induced in part by reforms to intellectual property rights (Maskus 2000; Santaniello et al. 2000), has concentrated ownership of biotechnology patents in the hands of a small number of US and EU conglomerates (Falcon 2000).

[5] This section draws on Anderson, Nielsen and Yao (2001b).

and Southeast Asia with the base case scenario of 2005, first without and then with China also enjoying a similar productivity shock. Key results are presented in Table 2(b) and the first set of columns of Table 3.

When those other countries adopt GM rice their output growth depresses the price of rice not only in their own countries (by up to 5 per cent) but also in other regions to a small extent (Scenario A in Table 2(a)). That discourages rice production slightly in those other regions including China. When China's adoption of GM rice also is included, as in Scenario B in Table 2(a), China's rice output growth dampens the price of rice in China but is not sufficiently large as to have much impact on international markets. Even so, China's exports of rice rise instead of falling as in Scenario A, and rice imports rise in the non-adopting regions.

The first set of columns of Table 3 reports the impact of these simulated technology and policy shocks on economic welfare of different regions, measured as equivalent variations in income. In Scenario A several other regions in addition to the GM-adopting ones benefit from the new rice technology, including China. With China also adopting, as in Scenario B, it gains vastly more of course (although that gain is not net of the cost of undertaking the research and disseminating the new technology): US$1.2 billion per year, compared with only $23 million if it does not adopt, which more than doubles the global economic gain from this technology's adoption. Only India and Australia lose slightly from GM rice adoption elsewhere.

Scenario 2: Selected countries including China adopt Bt cotton[6]

China is a significant net importer of cotton and net exporter of textiles and apparel, and would be even more so if 'voluntary' export restraints (VERs) on its textiles and apparel to the US and EU were not in place. Its self-sufficiency in plant fibres (primarily cotton) is projected to fall between 1995 and 2005 by just two percentage points to around 81% as the Uruguay Round and China's WTO commitments (except VERs on its textile and apparel) are implemented; and its textiles and apparel self-sufficiency is expected to grow slightly from 112 to 117 per cent (Table 1). For more than a decade there has been a keen interest in China in becoming less dependent on imports of both cotton and GM cotton technology. To that end, biotechnological research efforts in China are now bearing fruit with farmers being eager to adopt *Bt* cotton as and when it has become available. That began with four varieties being adopted in nine provinces in 1998, but has subsequently spread to perhaps one million hectares by 2000, or one-quarter of the total area sown to cotton in China – an amazingly rapid uptake (Huang et al. 2001; Pray et al. 2001).

Given that without GM cotton technology China is projected by 2005 to be producing and using around one-quarter of the world's plant fibres, and accounting for more than one-fifth of the world's imports of them (Table 1), its decision to embrace GM technology for cotton can be expected to have a big impact, via the terms of trade, on the economy not only of China but also of all other countries involved in fibre, textile and apparel markets. To get a sense of how large that might be, we compare the impact of GM-driven productivity growth of 5 per cent in cotton production in North America, the Southern Cone of South America (Argentina, Chile and Uruguay) and Southeast Asia with the base case scenario of 2005, first without and then with China also enjoying a

[6] This section draws on Anderson, Nielsen and Yao (2001a).

similar productivity shock, and then also with the remaining 'voluntary' export restraints on China's textile and apparel exports removed. Key results are presented in Table 2(b) and the middle column of Table 3.

When those other countries adopt *Bt* cotton their output growth depresses the price of cotton not only in their own countries (by 5-6 per cent) but also in other regions to a small extent (0.3-0.5 per cent -- Scenario A in Table 2(b)). That discourages cotton production in those other regions including China, but it encourages a small increase in textile and apparel output on most regions. When China's adoption of *Bt* cotton also is included, as in Scenario B in Table 2(b), China's cotton output growth is sufficiently large as to dampen further the price of cotton globally. That reduces the other GM-adopting regions' output growth and adds to the decline in cotton output in other regions. It also ensures a bigger increase in textiles and apparel output in China and, given the large share of China in global textile markets, a lesser increase or in some cases a decrease in the textile and apparel production of other regions. Not surprisingly, exports of cotton rise and cotton imports fall in the GM-adopting regions, and conversely for most other regions. The exception is in Scenario C for China, which assumes also the removal of the Multifibre Arrangement's VERs on Chinese exports to the US and EU (and that they are not replaced with safeguards!). In that case textile and apparel production becomes so much more profitable in China that its net imports of cotton rise – despite the *Bt* productivity growth -- and China crowds out more textile exports from other regions, especially other developing country suppliers.

The middle section of Table 3 reports the impact of these simulated technology and policy shocks on economic welfare of different regions, measured as equivalent variations in income. In Scenario A several other regions in addition to the GM-adopting ones benefit from the new cotton technology, including China. With China also adopting, as in Scenario B, it gains vastly more of course (but again the cost of undertaking the research and disseminating the new technology needs to be deducted): US$1.03 billion per year, compared with only $0.09 billion if it does not adopt, which more than doubles the global economic gain from this technology's adoption. The gain to China quadruples if the remaining VERs on China's textile and apparel exports are lifted in 2005 (Scenario C). As is clear from the bottom rows of Table 3, only a small part of that difference is because of more *Bt* cotton being sown in China as a result of VER removal; the majority of it is because more resources in China would be allocated to textile and apparel manufacturing, for which China has a strong comparative advantage that it has not been able to fully exploit because of VERs. The gain to the world as a whole from the removal of China's VERs (and assuming they are not replaced with safeguards) turns out to be even greater than the gains from GM adoption: global gains in Scenario C are $5.2 billion compared with Scenario B's $1.7 billion. Consumers in the US and EU are major economic gainers from VER removal, while producers/exporters of textiles and apparel in South and Southeast Asia and other developing countries lose a little because of the greater competition from China.

It is interesting to observe the changes in China's terms of trade for the 3 scenarios. The adoption of GM cotton by other regions will lead to the increase in cotton output and lower the world price, which improves China's terms of trade as China is a major cotton importer. Because China is also a major textile and clothing exporter, when China also adopts GM cotton it, the cheaper domestic cotton supply will translate into an expansion of textile and clothing export and as a result, the terms of trade gains from lower import price of cotton is partially offset by the lower export price of textile and clothing. But all those factors affecting China's terms of trade look trivial when compared to the removal of the VERs on China's textile and clothing export (Scenario C), which far more than offsets the terms of trade gain as a result of other regions adopting GM cotton (Scenario A). The overall large welfare gain to China in Scenario C – despite its terms of trade loss due to China's adoption of GM cotton and the VERs removal for China -- highlights the serious existing distortion caused by VERs on China's textile and clothing and the room for growth of China's textile and clothing sector, in which China has strong comparative advantage. It also indicates that the potential benefits to China of adopting GM cotton go well beyond its cotton crop sector.

Scenario 3: Selected countries including China adopt GM maize and soybean

The most widespread adoption of GM biotechnology in global cropping has been in soybean, followed by maize. In China these two are among the crops for which extensive field trials have been undertaken and, according to Huang et al. (2001), they are close to being ready for commercial release, were the government to allow it. Hence we again compare our base case projection with projected results for 2005 of several regions (North America including Mexico, the Southern Cone of South America, and Southeast Asia) adopting GM technology for these crops first without and then with China also adopting. As in the cotton case, we assume a 5 per cent productivity improvement in the relevant sectors of the GTAP model's adopting regions for the production of coarse grains and oilseeds. Results are shown in Table 2(b) and the final set of columns of Table 3.

When just the other regions adopt (Scenario A), China's output of these products falls slightly as is true for the other non-adopting regions, while it rises in the adopting regions even though prices of the GM products fall much more where the technology is adopted. And the same pattern shows up in the trade results: adopters increase their net exports while non-adopters, including China in Scenario A, increase their net imports of those two products. There are also some (smaller) impacts on the downstream livestock industries, but for simplicity they are not listed in Table 2 (although they are incorporated in the welfare effects). If China joins the GM-adopting group, as in Scenario B in Table 2(b), its production and exports of these products expand instead of shrinking. China's faster productivity growth in these products drives down their price in China a further 5 per cent.

The national economic welfare effects for China are very similar in magnitude in this case as for the case of cotton: a small gain for China if it does not adopt GM technology, and a much bigger gain ($0.8 billion per year) if it does adopt. Since China accounts for a much smaller share of global maize and soybean markets than the rice or cotton markets, its GM adoption has less effect on other countries in terms of the percentage change in world welfare between the 2 scenarios in this case (Table 3).

Scenario 4: Effects of bans on imports of Chinese food products

Were GM technology to be adopted for all four crops simultaneously by these same countries including China (and assuming China's VERs on textiles and clothing are still in place), the combined welfare effect in 2005 for China would be $3.0 billion per year. By how much would that sum be reduced if the adoption of GMO technology in China caused some countries to ban imports of Chinese food products? If only Western Europe were to ban Chinese foods, it would reduce the Chinese welfare gain only a little, namely by $0.5 billion (and reduce Western European welfare almost as much). But if Northeast Asia also were to ban Chinese farm products, the welfare loss would be much greater for China: it would reduce by four fifths the gains from GM adoption. The reason for the effect being so much more dramatic if Northeast Asia also bans Chinese goods is because China exports farm products much more (almost four times as much in 2005) to its neighbours than to Western Europe. These results are included simply to make the point that the welfare gains from GM adoption depend crucially on retaining market access abroad.

3. Conclusions

Clearly, China has a great deal to gain economically from moving down the GM path if there are no environmental externalities and no adverse consumer reactions. Rice and cotton would each contribute to Chinese economic welfare more than $1 billion per year, and maize and soybean combined would add an additional $0.8 billion. To these gross benefits need to be subtracted the cost of the R&D necessary to develop and disseminate the new technology, and the cost of any negative environmental externalities associated with the release of these GM products into the rural environment.

But what about the adverse consumer reactions to GMOs? Cotton is not very contentious as a fibre, and being all used domestically the question of market access abroad does not arise. Coarse grains and oilseeds also have been and are projected to remain import-competing industries in China, but that does not mean consumer attitudes abroad are irrelevant, for two reasons. One is that those attitudes abroad can influence Chinese consumer attitudes, and if that led to demands for GM labeling and enough consumers in China chose to avoid GM versions of those products, a proportion of the GM crop may have to be disposed of in international markets. The second reason for concern is that coarse grains and oilseeds are used for feeding animals and fish, as well as being inputs into various processed foods – and some of those products are being exported. Hence China has a vested interest in ensuring that the GM debate abroad does not lead to excessive denials of market access for GM products. Once it is a member of the WTO, China will be in a position to use its weight in that forum to argue against such actions.

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Table 1: China's share of the world market for selected farm products, and its self-sufficiency[a] in those products, 2005[b]

(per cent)

	Production	*Consumption*	*Exports*	*Imports*	*Self-Sufficiency 1995*	*Self-Sufficiency 2005*
Rice	27	27	4	4	100	100
Wheat	12	14	0	14	83	83
Coarse grain	8	8	3	3	102	99
Oilseeds	10	10	3	2	106	100
Vegetable oils	7	9	1	14	75	73
Livestock	5	5	0	0	101	100
Meats & dairy	3	3	2	1	106	103
Plant fibres	23	28	0	22	83	81
Textiles/apparel	13	10	21	9	112	117
All agric.					**99**	**97**

[a] Self sufficiency is defined as domestic output as a percentage of total domestic use, which includes both domestically produced and imported products. All are evaluated at domestic market prices. The 1995 numbers have been adjusted slightly to reflect trend rather than actual yields in China that year, since seasonal conditions were adverse in 1995.

[b] These shares refer to the global economy as projected to 2005 by the GTAP model following the full implementation of the Uruguay Round and the partial implementation (as promised by 2005) of the commitments made in negotiations for China's accession to WTO. Domestic values have been converted to international prices by adjusting according to the extent of domestic market distortion as reflected in the GTAP base data projected to 2005.

Source: Authors' GTAP projections using the Version 4.0 GTAP database

Table 2: Changes in production, market prices, exports and imports (%)

(a): Rice scenarios (A=all but China adopt; B=all adopt)

			China	NAm	SCone	India	SSAfri-	NEAsia	SEAsia	WEurope	ANZ
Production	Rice	A	-0.1	-0.5	0.4	-0.4	-0.2	-0.1	1.8	-1.2	-1.4
		B	0.2	-0.5	0.4	-0.4	-0.2	-0.1	1.7	-1.3	-1.4
MarketPrice	Rice	A	0.0	-2.1	-2.7	-0.1	0.0	0.0	-4.7	-0.2	0.0
		B	-3.5	-2.1	-2.7	-0.1	0.0	0.0	-4.7	-0.2	0.0
Export	Rice	A	-3.7	-0.9	1.7	-4.5	-3.8	-7.6	6.5	-3.1	-4.5
		B	3.9	-1.2	1.5	-4.9	-3.8	-8.0	6.1	-3.2	-4.7
Import	Rice	A	6.1	2.7	0.7	-0.4	2.0	3.1	-2.2	0.8	3.5
		B	3.0	2.8	0.7	-0.6	2.2	3.4	-2.2	0.8	3.6

… continued

Table 2 (continued): Changes in production, market prices, exports and imports (%)
(b): Cotton scenarios (A=all but China adopt; B=all adopt; C=all adopt with China's MFA removed)

			China	NAm	SCone	India	SSAfri-	NEAsia	SEAsia	WEurope	ANZ
Production	Cotton	A	-1.1	4.7	6.1	-0.2	-3.6	-4.7	2.3	-2.9	-5.1
		B	2.1	3.1	5.5	-0.2	-4.8	-6.0	2.2	-3.4	-5.7
		C	9.2	3.5	5.8	-0.3	-3.6	-4.9	2.1	-3.4	-5.6
	Textile/App.	A	0.2	0.2	0.1	-0.1	0.0	0.0	0.1	-0.1	0.0
		B	1.4	0.1	0.0	-0.1	-0.1	-0.3	-0.1	-0.3	-0.3
		C	9.7	-2.7	0.1	-1.3	-0.1	-0.6	-2.5	-1.5	0.1
MarketPrice	Cotton	A	-0.3	-4.8	-4.9	-0.1	-0.3	-0.3	-6.2	-0.3	-0.3
		B	-5.8	-4.9	-5.0	-0.1	-0.5	-0.4	-6.3	-0.3	-0.4
		C	-3.5	-4.9	-5.0	-0.5	-0.4	-0.3	-6.3	-0.3	-0.3
	Textile/App.	A	-0.1	-0.1	-0.1	0.0	-0.1	0.0	-0.1	0.0	0.0
		B	-0.5	-0.1	-0.1	-0.1	-0.2	-0.1	-0.1	0.0	-0.1
		C	0.3	-0.5	-0.1	-0.5	-0.1	0.0	-0.2	-0.1	0.0
Export	Cotton	A	-10.7	10.6	12.2	-8.2	-6.9	-8.1	15.8	-4.7	-9.9
		B	11.7	7.1	11.1	-8.8	-9.1	-12.4	14.2	-5.6	-11.1
		C	0.7	11.0	11.6	-7.6	-7.0	-7.5	15.0	-5.6	-11.0
	Textile/App.	A	0.2	0.4	0.2	-0.1	0.3	-0.1	0.2	-0.1	-0.1
		B	1.9	0.0	-0.1	-0.4	0.3	-0.4	-0.2	-0.5	-0.4
		C	18.9	-0.9	-0.3	-4.5	-3.9	-2.0	-3.6	-2.5	0.1
Import	Cotton	A	4.7	-0.5	-1.7	4.3	3.3	0.1	-3.8	-0.4	2.2
		B	-4.1	-0.6	-1.7	4.3	3.1	-0.2	-3.9	-0.6	2.2
		C	8.0	-1.6	-1.6	3.4	3.3	-0.5	-5.3	-1.7	2.7
	Textile/App.	A	0.0	-0.1	0.0	0.1	-0.1	0.1	0.1	0.0	0.0
		B	-0.1	0.1	0.3	0.3	0.1	0.6	0.1	0.1	0.3
		C	6.1	7.6	-0.2	-1.9	-0.2	-0.5	-1.7	0.7	-0.1

… continued

Table 2 (continued): Changes in production, market prices, exports and imports (%)
(c): Soybean and maize scenarios (A=all but China adopt; B=all adopt)

			China	NAm	SCone	India	SSAfri-	NEAsia	SEAsia	WEurope	ANZ
Production	Grain	A	-0.9	1.3	3.4	0.0	-0.5	-6.3	1.0	-2.1	-1.7
		B	1.0	1.1	3.2	0.0	-0.5	-6.4	0.9	-2.3	-1.9
	Soybean	A	-1.4	2.8	4.0	-0.2	-0.7	-5.0	1.5	-5.4	-1.3
		B	1.2	2.4	3.9	-0.2	-0.7	-5.4	1.1	-5.7	-1.4
MarketPrice	Grain	A	-0.2	-5.1	-5.3	-0.1	-0.1	-0.7	6.3	-0.1	-0.2
		B	-5.4	-5.1	-5.3	-0.1	-0.1	-0.7	-6.3	-0.1	-0.2
	Soybean	A	-0.3	-5.2	-5.1	-0.1	-0.1	-0.6	-5.9	-0.4	-0.2
		B	-5.6	-5.2	-5.1	-0.1	-0.1	-0.6	-6.1	-0.4	-0.2
Export	Grain	A	-8.9	5.8	10.2	-9.4	-7.9	-7.7	7.8	-5.1	-11.3
		B	11.3	4.9	9.6	-10.0	-8.3	-8.4	6.6	-5.7	-13.3
	Soybean	A	-12.6	6.7	8.6	-11.6	-11.5	-11.5	6.0	-10.1	-13.9
		B	7.6	5.7	7.8	-12.5	-12.2	-12.3	4.8	-10.6	-15.1
Import	Grain	A	7.4	-0.9	-2.3	2.0	4.7	1.4	-1.8	0.6	5.7
		B	-3.5	-0.9	-2.3	2.0	4.7	1.4	-1.4	0.6	5.8
	Soybean	A	8.9	-1.8	-0.2	9.1	5.0	1.9	-3.2	1.4	5.2
		B	-1.5	-1.6	-0.2	9.5	5.2	1.8	-2.5	1.5	6.7

Source: Authors' GTAP simulation with version 4 database.

Table 3: Welfare Effects of Individual GM Crops for Selected Regions (millions of 1995 US dollars pa)

		Rice	Total	Tech	TOT	Alloc	Others	**Cotton**	Total	Tech	TOT	Alloc	Others	**Soybean/Maize**	Total	Tech	TOT	Alloc	Others
	China		26	0	13	12	2		92	0	42	35	16		14	0	33	6	-25
	NAm		45	66	-23	-2	4		358	442	-128	8	36		2476	3240	-779	-37	52
	SCone		11	19	-7	0	-2		47	63	-20	3	3		325	456	-171	18	22
	India		-26	0	-12	-4	-11		-23	0	-9	0	-14		-15	0	-4	8	-19
(a) all but	SSAfri		5	0	6	1	-2		-38	0	-32	6	-13		-12	0	-5	0	-7
China adopt	NEAsia		62	0	27	21	13		62	0	60	5	-4		831	0	509	304	18
	SEAsia		641	895	-74	-177	-2		300	208	58	6	29		208	287	-62	-5	-11
	WEurope		57	0	19	30	7		18	0	31	23	-35		775	0	186	708	-119
	ANZ		-7	0	-5	0	-1		-27	0	-16	-3	-8		-58	0	-34	-2	-22
	AllOthers		59	11	56	6	-13		34	30	14	36	-47		537	289	329	57	-138
	World		872	991	0	-113	-6		823	742	0	119	-38		5081	4271	0	1059	-249
	China		1203	1058	-8	158	-4		1029	611	7	135	276		794	664	30	88	12
	NAm		34	66	-31	0	-1		309	439	-153	2	20		2430	3235	-815	-28	36
	SCone		9	19	-7	0	-3		45	62	-22	3	1		314	456	-178	17	19
	India		-32	0	-14	-4	-13		-53	0	-21	-3	-29		-17	0	-5	9	-20
(b) all adopt	SSAfri		6	0	8	1	-3		-47	0	-40	11	-18		-14	0	-6	0	-8
	NEAsia		87	0	51	21	15		145	0	130	25	-10		886	0	547	314	25
	SEAsia		645	894	-85	-159	-5		271	207	30	13	22		195	286	-73	-5	-13
	WEurope		64	0	21	40	2		49	0	62	49	-62		819	0	190	753	-123
	ANZ		-12	0	-8	-1	-3		-27	0	-14	-3	-9		-63	0	-37	-2	-24
	AllOthers		75	11	73	10	-19		9	29	21	40	-82		542	289	347	53	-148
	World		2080	2048	0	66	-34		1728	1349	0	271	108		5886	4930	0	1199	-244

Table 3 (continued)

	Cotton		Total	Tech	TOT	Alloc	Others
(c) All adopt with China's VERs removed	China		4078	636	-859	2312	1989
	NAm		2444	440	1639	541	-175
	Scone		30	63	-31	-3	1
	India		-567	0	-225	-110	-233
	SSAfri		-75	0	-58	-1	-16
	NEAsia		186	0	26	27	133
	SEAsia		-190	207	-363	7	-41
	WEurope		704	0	549	315	-159
	ANZ		-60	0	-48	-14	3
	AllOthers		-1311	29	-628	-334	-379
	World		5239	1375	2	2741	1122

Source: Authors' GTAP simulation with version 4 database.

Table A1: Self-Sufficiency for Selected Products by Region (%), 2005

	ANZ	NEAsia	SEAsia	China	India	SAsia-	NAm	Mexico	LAm-	SCone	WEurope	EEFSU	MEastNAfr	SAfri	SSAfri-	ROW
Rice	105.4	100.0	112.2	99.8	105.8	100.7	129.7	72.4	97.8	112.8	69.0	97.1	48.9	79.7	94.1	95.8
Coarse Grain	100.8	17.8	75.7	99.1	100.3	98.9	119.3	86.9	86.3	141.7	94.0	97.9	80.1	86.1	100.3	99.1
Oilseeds	101.3	17.2	86.2	100.1	100.9	98.3	154.8	11.6	101.2	119.3	48.8	105.4	70.9	89.8	105.8	103.3
Vegetable Oils	97.6	84.0	165.3	73.3	89.1	42.9	105.4	84.7	101.9	178.1	97.9	91.3	60.1	67.1	92.8	92.1
Livestocks	107.0	98.0	96.2	100.3	100.1	100.0	99.2	116.4	98.0	103.6	101.2	104.3	90.1	99.8	119.6	99.4
Meat&Dairy	158.7	84.0	89.3	103.0	103.2	94.4	104.7	94.8	100.1	116.3	99.4	94.6	87.3	99.4	88.1	94.2
Plant Fibre	199.8	8.9	67.3	81.4	98.0	94.8	170.4	97.8	81.4	171.4	41.9	150.0	92.2	122.2	203.4	118.5
Textile/apparel	68.9	107.0	142.3	116.6	125.7	140.7	80.5	98.7	90.9	94.2	80.9	87.3	80.1	89.3	75.5	82.4

Source: Authors' GTAP projection with version 4 database.

Table A2: Shares of Output and Domestic Use for Selected Products by Region (%), 2005

Output	ANZ	NEAsia	SEAsia	China	India	SAsia-	NAm	Mexico	LAm-	SCone	WEurope	EEFSU	MEastNAfr	SAfri	SSAfri-	ROW	World
Rice	0.2	14.1	15.1	26.7	10.1	3.5	1.5	0.1	11.6	0.8	1.2	6.1	1.3	0.3	3.8	3.5	100.0
Coarse Grain	0.6	0.9	1.5	7.8	4.1	1.2	40.7	4.2	7.2	2.7	12.8	5.7	7.1	0.7	1.5	1.3	100.0
Oilseeds	1.1	0.8	3.3	9.9	21.5	6.4	22.4	0.1	9.9	8.2	4.7	2.7	1.6	0.6	4.8	2.0	100.0
Vegetable Oils	0.9	3.4	9.9	7.0	4.8	1.2	15.1	0.8	9.1	5.2	32.0	3.1	3.6	0.5	1.7	1.7	100.0
Livestocks	2.9	4.0	1.9	5.4	2.7	0.8	35.5	2.5	9.8	5.1	14.2	4.5	5.6	1.2	1.1	2.8	100.0
Meat&Dairy	2.8	10.6	1.3	3.5	2.5	0.7	21.3	2.3	6.8	3.5	32.3	4.6	4.3	0.9	0.5	2.0	100.0
Plant Fibre	1.9	0.4	7.7	23.3	13.8	5.0	16.1	1.1	5.6	2.2	2.7	5.0	7.0	0.8	6.1	1.2	100.0
Textile/apparel	0.6	20.0	5.1	13.4	4.4	2.1	15.2	1.2	6.4	2.6	19.1	4.3	2.8	0.5	0.8	1.5	100.0
Domestic Use																	
Rice	0.2	14.1	14.0	26.6	9.4	3.5	1.1	0.2	11.8	0.7	1.7	6.2	2.4	0.5	4.2	3.6	100.0
Coarse Grain	0.6	4.7	1.9	7.8	4.0	1.2	33.6	4.7	8.3	1.9	13.3	5.7	8.7	0.7	1.5	1.3	100.0
Oilseeds	1.1	4.5	3.7	9.6	21.1	6.4	14.3	1.2	9.5	6.8	10.0	2.5	2.2	0.6	4.5	1.9	100.0
Vegetable Oils	0.9	4.0	5.8	9.2	5.0	2.3	14.2	0.9	8.6	2.9	32.9	3.4	5.5	0.8	1.8	1.7	100.0
Livestocks	2.7	4.1	1.9	5.4	2.7	0.8	35.8	2.2	9.9	4.9	14.1	4.3	6.3	1.2	0.9	2.8	100.0
Meat&Dairy	1.7	11.8	1.4	3.4	2.4	0.8	20.2	2.4	6.8	3.0	32.7	4.9	4.8	0.9	0.6	2.0	100.0
Plant Fibre	0.9	3.9	10.9	27.6	13.8	4.9	9.3	1.0	6.5	1.3	4.9	3.2	7.2	0.7	3.0	1.0	100.0
Textile/apparel	0.8	18.3	3.4	10.1	3.4	1.3	18.1	1.2	6.8	2.7	22.8	4.7	3.2	0.6	1.0	1.6	100.0

Source: Authors' GTAP projection with version 4 database.

Table A3: Shares of Export and Import for Selected Products by Region (%), 2005

Export	ANZ	NEAsia	SEAsia	China	India	SAsia-	NAm	Mexico	LAm-	SCone	WEurope	EEFSU	MEastNAfr	SAfri	SSAfri-	ROW	World
Rice	0.7	1.2	44.7	4.2	16.5	6.1	12.4	0.0	4.5	3.0	5.0	0.1	0.8	0.0	0.1	0.6	100.0
Coarse Grain	0.4	0.1	0.6	3.2	0.1	0.0	56.5	0.1	0.4	7.2	26.2	2.0	0.7	1.5	0.5	0.4	100.0
Oilseeds	0.4	0.3	1.6	3.4	1.6	0.3	60.0	0.2	6.9	9.6	8.5	3.4	0.6	0.4	1.9	0.8	100.0
Vegetable Oils	1.0	0.5	30.4	0.8	1.5	0.2	10.0	0.6	7.9	14.8	25.7	2.0	2.1	0.4	1.0	1.1	100.0
Livestocks	6.3	0.2	0.1	0.4	0.1	0.0	16.0	10.2	0.3	4.9	44.7	6.4	5.2	0.2	4.8	0.2	100.0
Meat&Dairy	11.3	2.2	2.7	2.0	1.1	0.0	15.0	0.1	3.4	5.8	52.0	2.7	0.4	0.9	0.1	0.2	100.0
Plant Fibre	4.8	0.5	0.7	0.5	0.6	3.3	34.4	1.9	3.4	5.3	7.5	14.5	4.6	1.7	15.3	1.1	100.0
Textile/apparel	0.3	19.3	11.0	21.6	4.1	4.4	4.8	0.9	1.5	0.1	23.9	2.9	3.6	0.5	0.1	1.0	100.0
Import																	
Rice	0.4	2.8	15.6	4.5	0.1	4.6	3.2	1.1	10.4	0.4	15.0	3.9	23.0	3.2	9.2	2.6	100.0
Coarse Grain	0.4	28.3	3.6	3.5	0.0	0.1	3.1	4.7	8.8	0.7	28.1	2.7	13.1	2.1	0.4	0.4	100.0
Oilseeds	0.3	25.2	4.3	2.0	0.1	0.6	3.0	7.4	4.8	0.1	44.1	2.2	4.8	0.8	0.0	0.3	100.0
Vegetable Oils	1.0	4.2	4.6	14.4	3.0	7.3	4.8	1.4	5.1	0.5	31.6	3.4	13.9	1.9	1.4	1.4	100.0
Livestocks	1.0	2.6	2.1	0.0	0.0	0.0	22.9	0.3	5.1	0.1	41.1	1.2	22.8	0.2	0.0	0.5	100.0
Meat&Dairy	0.4	15.3	4.3	0.8	0.2	0.4	4.5	1.3	3.5	0.5	54.1	5.6	6.1	1.0	0.8	1.1	100.0
Plant Fibre	0.0	16.9	16.3	22.0	1.3	2.8	1.4	1.7	8.0	0.6	17.2	5.1	5.4	0.9	0.1	0.1	100.0
Textile/apparel	1.2	12.9	4.1	8.8	0.3	1.3	16.4	0.9	3.2	0.6	37.7	4.6	5.2	0.6	0.9	1.3	100.0

Source: Authors' GTAP projection with version 4 database.

Table A4: Regional aggregates within the GTAP model

Abbreviation	
ANZ	Australia and New Zealand
NEAsia	North East Asia (Japan, Hong Kong, Korea and Taiwan)
SEAsia	South East Asia
Sasia	South Asia
Nam	North America (Canada, Mexico and USA)
Scone	Southern Cone (Chile, Argentina and Uruguay)
Lam	Rest of Latin America
Weurope	Western Europe
EEFSU	Eastern Europe and Former Soviet Union
MeastNAfr	Middle East and North Africa
Safri	South Africa
SSAfrica	Rest of Sub-Sahara Africa
ROW	Rest of the World

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