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CHINA, GMOS AND WORLD TRADE IN AGRICULTURAL AND TEXTILE PRODUCTS

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Abstract. China's rapid industrialization and recent accession to the WTO makes it difficult for the country to maintain self-sufficiency in agricultural products. Genetic modification technology could ease the situation, but is not without controversy. This paper focuses on the implication of GMO controversy for China. It explores the potential economic effects of China's 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 that are opposed to GMOs, and/or on the liberalization of China's trade in textiles and apparel.

1. INTRODUCTION

The use of modern biotechnology to create genetically modified organisms (GMOs) through agricultural research has generated exuberance from those looking forward to a new 'green revolution'. In China especially, biotechnology is seen as a way of boosting the country's food, feed and fibre security via greater agricultural self-sufficiency. Such new technology has the potential to leaven the forces of industrialization, which over time tends to draw mobile resources away from agriculture in a trend that may intensify following China's accession to the World Trade Organization (WTO). For these reasons, and to avoid becoming dependent on imported biotechnology, China has been investing heavily in biotech research since the mid-1980s (Huang *et al.* 2001).[1] By 2001 it had the fourth largest area sown to GM crops, after the United States, Argentina and Canada (James 2002), and its biotech research capacity is believed to be inferior only to that of the United States and the European Union.

GMOs have also attracted strong criticism. The opposition comes from groups concerned about the safety of genetically modified foods, the environmental impact of growing genetically engineered plants, and the ethics related to using

[1] These apparent reasons are not necessarily justifiable in economic terms. For example, it may be cheaper to import biotechnology than try to produce it domestically, or to import food rather than try to reduce domestic costs of crop production via new technologies. And the adoption of new crop technologies need not keep workers from leaving agriculture, especially if the new technologies are particularly labour-saving.

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that technology *per se*. Scepticism towards 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. While some countries (e.g. Sri Lanka) have taken the extreme step of banning the importation of GM products, others (e.g. Japan, Korea, Thailand and perhaps Hong Kong) are introducing mandatory GM labelling laws. In contrast, farmers in North and South America are readily adopting GM crops, and citizens there have generally (perhaps unwittingly) accepted that development.

What are the implications of the GMO controversy for China? Since China is potentially 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[2] risks associated with adopting GM technology against the food, feed and fibre security and other perceived benefits associated with producing or importing that technology.

This paper quantifies the potential economic effects of China's not adopting versus its adopting GMOs when some of its trading partners adopt that technology, as well as the impact of its major trading partners' denying market access to China's food exporters. The analysis uses the computable general equilibrium model of the global economy known as GTAP (Global Trade Analysis Project), projected forward to 2005, by which time Uruguay Round trade liberalization commitments should be implemented and China should be well advanced in implementing its WTO accession commitments. The analysis focuses on four GM crops: rice, cotton, corn and soybeans. The effects are shown to depend to a considerable extent on the trade policy stance taken in high-income countries opposed to GMOs, and on the liberalization of China's trade in textiles and apparel. Implications for China are arrived at 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 the adoption of GM-inclusive seeds by subsets of farmers the world over. Hence an empirical modelling approach is called for. We use a well-received empirical model of the global economy (the GTAP model) to examine the effects of some countries' adopting the new GMO technology, first if China does not adopt the technology and then if it also adopts it. Specifically, the effects of an assumed degree of GM-induced productivity growth in selected countries are explored for rice, cotton, maize and soybean.

As it is a general equilibrium model, GTAP describes vertical and horizontal linkages between all product markets, both within the model's individual countries and regions and 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 we use as a basis for projecting to 2005 (following similar modelling work by Anderson *et al.* (1997), which assumes that

[2] Recently Britain and Japan banned the importation of Chinese soy sauce, because the soybeans it was produced from may have contained GMOs (as they may have been imported from the USA).

Uruguay Round commitments of WTO members are fully implemented by 2005). In addition, the present study assumes that China's WTO accession commitments to open up are mostly implemented by 2005, with the exception of textiles and apparel. This base projection from 1995 to 2005 assumes no agricultural biotechnology adoption, and is to be compared with alternative projections which assume that a subset of countries adopt GM crops. To make the results easier to comprehend, 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).[3] But we present results only for selected regions: China, North America (NAm), the Southern Cone of Latin America (SCone: Argentina, Chile and Uruguay), India, Sub-Sahara Africa other than South Africa (SSAfri-), Northeast Asia (NEAsia), Southeast Asia (SEAsia), West Europe (WEurope), and Australia and New Zealand (ANZ).

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 soybeans 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; Nelson *et al.* 1999). Available empirical evidence (e.g. USDA 1999; James 2002) does, however, suggest that cultivating GM crops has general cost-reducing effects.[4] 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%, thereby rightward-shifting the supply curve for the GM crop to that extent.[5] Demanders of primary agricultural products such as maize

[3] The GTAP (Global Trade Analysis Project) model is a multi-regional, static, applied general equilibrium model based on neoclassical 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 GTAP database used here. The model is solved with GEMPACK software (Harrison and Pearson 1996).

[4] 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).

[5] Owing 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' labelling 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, may even keep track of which country is the home of the (typically multinational) firm receiving the technology fee.

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

	Production	*Consumption*	*Exports*	*Imports*	*Self-sufficiency 1995*	*Self-sufficiency 2005*
Rice	29	28	6	4	101	100
Wheat	14	16	0	13	85	85
Coarse grain	10	10	4	4	104	100
Oilseeds	9	9	3	2	108	99
Vegetable oils	7	9	1	4	73	70
Livestock	5	5	0	0	101	100
Meats & dairy	4	4	2	1	110	104
Plant fibres	24	29	0	28	82	78
Textiles/apparel	15	11	28	14	111	125
All agriculture					**99**	**96**

[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.

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 who are able to buy cheaper cotton.

The widespread adoption of GM varieties in certain regions will affect international trade flows depending on how much the crop in question is traded. To the extent that trade is not further restricted and is not currently subject to binding quantitative restrictions, world market prices for these products will have a tendency to decline and thus to benefit regions that are net importers of the products. For exporters, the lower price may or may not boost their trade in value terms, 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 is, as in China's case, a large global player in some of the markets affected.

The relative importance of China globally in these primary and processed agricultural sectors is evident in Table 1, as are its self-sufficiency ratios as of 1995 and 2005. The latter reveal that during the decade to 2005 China's self-sufficiency in agricultural products is expected to fall from 99% to 96% in the course of China's economic growth and accession to the 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

China is virtually self-sufficient in rice, and that is expected to change little by 2005 in the absence 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 on whether or not to embrace GM technology for rice can be expected to have a big impact, via the terms of trade, not only on China but also on 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% in rice 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's enjoying a similar productivity shock. Key results are presented in Table 2 and the first set of columns of Table 3.

When those other countries adopt GM rice, their output growth will depress the price of rice not only in their own countries (by up to 4.5%) but also, to a small extent, in other regions (scenario A in Table 2). That will discourage rice production slightly in those other regions, including China. When China also adopts GM rice, as in scenario B in Table 2, China's rice output growth will cause the price of rice to fall by 3.6% in China, and by 1.9% in international markets (instead of just by 0.9% if China does not adopt GMOs). China's exports of rice will rise, instead of changing little as in scenario A, and rice imports will 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 the 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's also adopting GM technology, as in scenario B, the country gains vastly more, of course (although that gain is not net of the cost of undertaking the research and disseminating the new technology): US$1.1 billion per year, compared with only US$4 million if it does not adopt, which more than doubles the global economic gain from this technology's adoption.

Scenario 2: Selected countries including China adopt Bt cotton

China is a significant net importer of cotton and a net exporter of textiles and apparel, and would be an even greater exporter of the latter if 'voluntary' export restraints (VERs) on its textiles and apparel to the Unites States and the European Union were not in place. Its self-sufficiency in plant fibres (primarily cotton) is projected to fall between 1995 and 2005 by four percentage points to around 78% as the Uruguay Round and China's WTO commitments (except VERs on its textiles and apparel) are implemented; and its textiles and apparel self-sufficiency is expected to grow slightly from 111% to 125% (Table 1). For more than a decade there has been a keen interest within China in becoming less dependent on imports of both cotton and GM cotton technology. To

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

	China	*NAm*	*SCone*	*India*	*SSAfr-*	*NEAsia*	*SEAsia*	*WEurope*	*ANZ*
(*a*) Rice scenarios (A = all but China adopt; B = all adopt)									
Production									
Rice									
A	−0.2	−1.3	0.4	−0.8	−0.4	−0.1	3.3	−3.3	−3.0
B	0.3	−1.6	0.4	−0.9	−0.4	−0.1	3.1	−3.5	−3.1
Market price									
Rice									
A	0.0	−1.8	−2.8	−0.1	0.0	0.0	−4.5	−0.2	0.0
B	−3.6	−1.8	−2.8	−0.1	0.0	0.0	−4.6	−0.2	0.0
Export									
Rice									
A	0.0	−0.7	0.2	−0.4	−0.2	−0.1	1.6	−1.6	−1.4
B	15.3	−2.6	0.9	9.4	4.7	1.9	−1.9	−0.4	3.9
Import									
Rice									
A	12.6	5.3	2.4	−0.3	4.3	1.2	−3.2	1.8	7.5
B	5.4	5.5	2.5	−1.0	4.9	1.4	−3.3	1.9	7.7
(*b*) Cotton scenatios (A = all but China adopt; B = all adopt; C = all adopt with China's MFA removed)									
Production									
Cotton									
A	−2.1	9.9	10.7	−0.3	−5.8	−7.7	4.3	−5.4	−8.2
B	4.2	6.2	9.3	−0.3	−7.8	−10.3	4.1	−6.6	−9.5
C	32.6	15.0	13.7	−0.6	0.2	0.1	4.5	−6.0	−5.4
Textile/app.									
A	0.3	0.3	0.1	−0.1	0.1	−0.1	0.2	−0.1	−0.0
B	1.9	0.1	−0.1	−0.2	−0.1	−0.6	−0.1	−0.3	−0.7
C	42.5	−16.7	0.5	−11.0	−2.6	1.6	−1.3	−14.7	0.7
Market price									
Cotton									
A	−0.5	−4.7	−4.2	−0.1	−0.8	−0.5	−5.5	−0.3	−0.4
B	−5.5	−4.8	−4.4	−0.1	−1.1	−0.6	−5.6	−0.4	−0.5
C	3.2	−4.6	−3.8	−2.2	−0.2	0.1	−5.3	−0.4	−0.2
Textile/app.									
A	−0.1	−0.1	−0.1	0.0	−0.1	0.0	−0.1	0.0	0.0
B	−0.4	−0.1	−0.1	−0.1	−0.2	−0.1	−0.1	0.0	−0.1
C	1.6	−1.2	0.0	−2.5	−0.2	0.2	0.1	−0.7	0.2
Export									
Cotton									
A	−16.7	23.3	20.0	−14.2	−9.3	−12.9	28.6	−8.8	−16.1
B	23.7	14.7	17.5	−15.8	−12.6	−20.7	24.3	−10.9	−18.5
C	−37.4	54.9	25.2	0.3	0.4	14.0	34.9	−9.3	−11.0
Textile/app.									
A	0.3	0.6	0.2	−0.2	0.8	−0.2	0.2	−0.3	−0.2
B	1.8	−0.3	−0.7	−0.3	1.2	−0.5	0.1	−0.8	−1.0
C	74.6	−2.7	−4.9	−22.6	−33.1	0.5	−2.5	−20.5	−5.9
Import									
Cotton									
A	7.8	−2.2	−2.1	7.0	3.4	0.2	−6.6	−0.7	3.0
B	−7.4	−2.2	−2.2	7.6	2.5	−0.3	−6.6	−1.0	3.0
C	70.0	−8.5	−1.5	−3.0	5.7	2.1	−7.4	−12.9	6.4

Table 2. Continued.

	China	*NAm*	*SCone*	*India*	*SSAfr-*	*NEAsia*	*SEAsia*	*WEurope*	*ANZ*
Textile/app.									
A	0.0	−0.2	0.0	0.2	−0.1	0.2	0.1	0.0	0.1
B	0.1	−0.1	0.9	1.0	0.3	1.1	0.5	0.0	0.6
C	32.3	33.1	−3.5	−20.9	−0.6	−3.5	−2.6	7.9	−2.1
(*c*) Soybean and maize scenarios (A = all but China adopt; B = all adopt)									
Production									
Maize									
A	−1.6	2.5	5.7	−0.1	−1.4	−9.8	1.9	−4.2	−3.2
B	1.6	2.1	5.3	−0.1	−1.5	−10.1	1.6	−4.6	−3.5
Soybean									
A	−2.5	5.5	6.8	−0.3	−2.1	−8.3	2.5	−10.3	−2.3
B	2.2	4.7	6.6	−0.4	−2.2	−8.9	1.9	−10.7	−2.5
Market price									
Maize									
A	−0.3	−5.0	−4.8	−0.1	−0.2	−1.2	−6.1	−0.1	−0.3
B	−5.3	−5.0	−4.9	−0.1	−0.2	−1.3	−6.2	−0.1	−0.3
Soybean									
A	−0.5	−5.0	−4.5	−0.2	−0.3	−0.9	−5.7	−0.4	−0.3
B	−5.4	−5.1	−4.6	−0.2	−0.3	−1.0	−5.9	−0.5	−0.3
Export									
Maize									
A	−15.9	11.4	17.6	−17.9	−14.4	−10.5	16.0	−10.2	−20.7
B	23.9	9.1	16.4	−19.2	−15.4	−11.9	13.8	−11.3	−24.4
Soybean									
A	−21.8	13.0	12.8	−21.2	−20.0	−19.0	12.4	−18.9	−24.8
B	14.2	11.3	11.3	−22.7	−21.1	−20.8	10.6	−19.7	−26.5
Import									
Maize									
A	17.0	−1.5	−2.9	2.4	9.7	2.9	−4.0	1.4	10.1
B	−5.0	−1.5	−3.1	2.3	9.8	2.9	−3.2	1.5	10.3
Soybean									
A	15.4	−3.6	1.5	17.6	8.8	3.6	−6.8	2.6	9.6
B	−3.7	−3.5	1.4	18.4	9.1	3.4	−6.1	2.7	12.2

Source: Authors' GTAP simulation with version 4 database.

that end, biotechnological research efforts in China are now bearing fruit, with farmers eager to adopt Bt cotton as and when it becomes available. This process began with four varieties being adopted in nine provinces in 1998, but by 2000 it had spread to perhaps a million hectares, 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, it is estimated that by 2005 China will be producing around one-quarter of the world's plant fibres and accounting for more than one-quarter of the world's consumption and imports (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

Table 3. Welfare effects of individual GM crops for selected regions (US$1995 millions per year)

	Rice					*Cotton*					*Soybeans/maize*				
Scenario	*Total*	*Tech.*	*TOT*	*Alloc.*	*Others*	*Total*	*Tech.*	*TOT*	*Alloc.*	*Others*	*Total*	*Tech.*	*TOT*	*Alloc.*	*Others*
(A) all but China adopt															
China	4	0	4	0	−1	15	0	11	11	−7	32	0	17	18	−4
NAm	50	63	−16	2	0	318	395	−87	7	2	2,366	3,272	−700	−188	−17
SCone	12	19	−7	0	−1	49	67	−17	2	−2	338	533	−199	20	−16
India	−18	0	−13	−5	0	−23	0	−23	−1	1	3	0	−16	23	−4
SSAfr-	5	0	4	2	0	−41	0	−64	19	3	−23	0	−25	0	2
NEAsia	57	0	12	48	−2	71	0	68	7	−4	921	0	418	547	−44
SEAsia	504	1,094	−99	−450	−40	275	250	34	4	−13	222	374	−107	−26	−18
WEurope	88	0	34	56	−3	79	0	44	37	−2	1,589	0	262	1,364	−37
ANZ	−2	0	−2	0	0	−8	0	−7	−1	0	−30	0	−32	4	−2
All others	103	11	83	17	−8	120	33	40	61	−14	738	299	383	110	−54
World	**804**	**1,188**	**0**	**−330**	**−54**	**856**	**745**	**0**	**146**	**−35**	**6,156**	**4,478**	**0**	**1,872**	**−194**
(B) All adopt															
China	1,110	1,068	−31	137	−64	340	665	−125	−160	−41	830	777	31	72	−49
NAm	36	63	−34	6	1	286	388	−99	−9	5	2,347	3,264	−729	−170	−17
SCone	10	19	−9	0	−1	52	66	−18	6	−2	328	532	−208	19	−16
India	−23	0	−19	−5	0	−26	0	−33	6	1	0	0	−18	23	−4
SSAfr-	7	0	5	2	0	−52	0	−87	31	4	−27	0	−29	0	2
NEAsia	65	0	21	46	−2	291	0	237	55	−1	965	0	445	562	−42
SEAsia	523	1,093	−118	−411	−41	312	250	46	30	−13	203	373	−122	−31	−18
WEurope	114	0	37	79	−2	122	0	63	54	4	1,687	0	276	1,447	−36
ANZ	0	0	0	0	0	−11	0	−10	−1	0	−36	0	−37	3	−2
All others	177	11	146	31	−11	169	32	26	129	−18	739	298	391	103	−54
World	**2,019**	**2,255**	**0**	**−114**	**−121**	**1,483**	**1,402**	**0**	**141**	**−60**	**7,036**	**5,244**	**0**	**2,028**	**−236**

Table. 3 Continued.

	Rice					*Cotton*					*Soybeans/maize*				
Scenario	*Total*	*Tech.*	*TOT*	*Alloc.*	*Others*	*Total*	*Tech.*	*TOT*	*Alloc.*	*Others*	*Total*	*Tech.*	*TOT*	*Alloc.*	*Others*
(C) All adopt with China's VERs removed															
China						7,433	757	−4,914	12,378	−788					
NAm						8,698	399	5,788	2,527	−17					
SCone						−31	67	−67	−41	9					
India						−2,370	0	−1,605	−989	225					
SSAfr-						−224	0	−174	−70	21					
NEAsia						535	0	263	36	236					
SEAsia						325	250	58	−29	47					
WEurope						8,266	0	4,798	3,436	33					
ANZ						−342	0	−300	−64	22					
All others						−5,863	33	−3,812	−2,289	205					
World						**16,426**	**1,506**	**34**	**14,893**	**−7**					

Source: Authors' GTAP simulation with version 4 database.

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% 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's enjoying a 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 columns 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 4.2%–5.5%) but to a small extent also in other regions (0.1%–0.8%: 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 in all adopting regions and some non-adopting regions. When China's adoption of Bt cotton also is included, as in scenario B in Table 2(b), China's cotton output growth becomes large enough to dampen the global price of cotton further. That reduces the output growth of other GM-adopting regions and adds to the decline in cotton output in non-adopting regions. It also ensures a bigger increase in textiles and apparel output in China and, given China's large share 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 in addition the removal of the Multifibre Arrangement's VERs on Chinese exports to the USA and EU (and that they are not replaced with safeguards). In that case textile and apparel production will expand so much in China that its net imports of cotton will rise – despite the Bt productivity growth – and China will crowd out more textile exports from other regions. The international price of cotton will fall 1.6% if China does not, and 2.9% if it does, adopt GM cotton. The latter will drop to become a 1.0% fall if China's VERs also are removed, because of the greater domestic demand for cotton by the textile industry in China. International trade in cotton will therefore be 0.7% lower if China does not adopt GM cotton, but 5.1% lower if China does adopt it, as it will then need to import less cotton.

The middle columns of Table 3 report the impact of these simulated cotton technology and policy shocks on the economic welfare of different regions, measured as equivalent variations in income. In scenario A several other regions in addition to the GM-adopting ones, including China, will benefit from the new cotton technology. With China's also adopting, as in scenario B, it will gain vastly more, of course (but again, the cost of undertaking the research and disseminating the new technology needs to be deducted): \$340 million per year, compared with only \$15 million if it does not adopt, which will almost double the global economic gain from this technology's adoption. The gain to China will increase 20-fold if the remaining VERs on China's textile and apparel exports are lifted in 2005 (scenario C). As is clear from the final panel of Table 3, only a small part of that difference is because more

Bt cotton will be sown in China as a result of VER removal; the majority of it is because more resources in China will be allocated to textile and apparel manufacturing, for which China has a strong comparative advantage that it has not been able to exploit fully because of VERs. The gain to the world as a whole from the removal of China's VERs (assuming they are not replaced with safeguards) turns out to be even greater than the gains from GM adoption: global gains in scenario C would be \$16.4 billion compared with scenario B's \$1.5 billion. Consumers in the USA and EU would be major economic gainers from VER removal, while producers/exporters of textiles and apparel in South Asia and other developing countries would suffer a loss because of the greater competition from China.

What happens to China's terms of trade in the three scenarios? The adoption of GM cotton by other regions will lead to an increase in cotton output and lower world prices, which will improve China's terms of trade as it is a major cotton importer. Because China is also a major textile and clothing exporter, when it too adopts GM cotton the cheaper domestic cotton supply translates into an expansion of textile and clothing exports, and as a result the terms-of-trade gains from the lower import price of cotton will be more than offset by the lower export price of textiles and clothing. But all those factors affecting China's terms of trade look trivial compared with the removal of the VERs on its textile and clothing exports (scenario C), which imposes a terms-of-trade loss of \$4.9 billion. The overall welfare gain to China in scenario C – despite its terms-of-trade loss arising from the country's adoption of GM cotton and the VERs removal for China – highlights the seriousness of the existing distortion in China's foreign trade caused by VERs on China's textile and clothing sector.

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

The most widespread adoption of GM biotechnology in global cropping has been in soybeans, 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, if the government were 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's also adopting. As in the case for cotton, we assume a 5% 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(c) and the final set of columns of Table 3.

When just the other regions adopt GM technology (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. Prices of the GM products fall much more where the technology is adopted. 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 domestic price a further 5%.

The national economic welfare effects for China are very similar in magnitude in this case as for the case of rice: 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 for rice or cotton markets, its GM adoption has less effect on other countries in terms of the percentage change in world welfare between the two scenarios in this case (Table 3). Even so, the international prices of these products fall an extra 0.5% when China joins the adopters.

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

Were GM technology to be adopted by these same countries, including China, for all four crops simultaneously (and assuming that China's VERs on textiles and clothing were still in place), the combined welfare effect in 2005 for China would be $2.3 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 $0.4 billion (and would reduce Western European welfare by 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 two-thirds the gains from GM adoption. The reason why the effect would be so much more dramatic if Northeast Asia were also to ban Chinese goods is that China exports far more farm products (estimated to be over three times as much by 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 China's 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 alone would contribute more than $1 billion per year to Chinese economic welfare, cotton would contribute $0.3 billion, and maize and soybeans combined would add a further $0.8 billion, assuming that the technology boosted total factor productivity by 5% and that there was no consumer resistance to, or trade restrictions on, GM products. From 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 adverse consumer reactions to GMOs? Cotton is not very contentious as a fibre, and as all of China's cotton is used domestically, the question of market access abroad does not arise (leaving aside the cottonseed issue). Coarse grains and oilseeds also have been, and are projected to remain, import-competing industries in China, but that does not mean that consumer attitudes abroad are irrelevant, for two reasons. First, those attitudes abroad can influence Chinese consumer attitudes, and if this then led to demands for GM labelling and enough consumers in China chose to avoid GM versions of those products, a proportion of the GM crop might have to be disposed of in international markets. Second, coarse grains and oilseeds are used for feeding animals and fish, as well as for 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. As a WTO member, China is now in a position to use its weight in that forum to argue against such actions.

Finally, what would such a productivity improvement do for food security in China? Domestic production of rice, maize and soybeans would be up to 1% greater if China adopted, instead of being 1% less if only other countries adopted (see table 2). Because of imperfect substitutability between domestic and foreign products, most of that difference in production would translate into greater domestic consumption. So, even though the food self-sufficiency ratio would change very little, food consumption and hence food security would increase with China's adoption of the new technology (assuming there is no perceived food safety risk associated with GMOs).

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