ECONOMIC IMPACTS OF GENETICALLY MODIFIED CROPS IN CHINA

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ABSTRACT

China has made a major investment in biotechnology research. Genetically modified (GM) cotton is widely adopted and the list of GM technologies in trials is impressive. At the same time there is an active debate on when China should commercialize its GM food crops. The overall goal of this paper is to provide an economy-wide assessment of these issues under various scenarios. Based on a unique data from empirical micro-level study and field trial in China and a modified GTAP model, our results indicate that the development of biotechnology has an important impact on China's production, trade and welfare. Welfare gains far outweigh the public biotechnology research expenditures. Most gains occur inside China. Policy makers should put less weight on the international dimension in making their decisions on biotechnology development.

JEL classification: C68, D58, F13, O33, Q17, Q18
Keywords: Economic impacts; Biotechnology; Genetically modified crops; China

INTRODUCTION

Biotechnology has spurred a worldwide debate since the technology uses genetic modification techniques. The debate has been going on for decades and has brought a significantly depressing impact on the supply of biotechnology. China was one of the first countries to introduce a GM crop commercially and currently has the fourth largest GM crop area, after the USA, Argentina, and Canada (James, 2002). China's agricultural biotechnology development is an interesting case and unique in many aspects. The public sector dominates the industry and the list of GM crops in trials differs from those being worked on in other countries (Huang et al, 2002a). The Chinese government views agricultural biotechnology as a tool to help China improve the nation's food security, raise agricultural productivity, increase farmer's income, foster sustainable development, and improve its competitive position in international agricultural markets (SSTC, 1990).

However, there is a growing concern among policy makers regarding the impacts of the ongoing global debate over biotechnology on China's agriculture and its biotech industry development. Under this situation, despite GM crops have continued to be generated in public research institutes, the approval of GM crops, particularly food crops, for commercialization has become more difficult since late 1998 (Huang et al., 2001). This reflects the influence of the global debate on GM crops on Chinese policymakers, in particular restrictions on imports to EU countries and export from North America. For example, the Ministry of Agriculture (MOA) announced three new regulations on the biosafety management, trade and labeling of GM farm products that took effect after March 20, 2002, which require importers of GM agricultural products to apply for official safety verification approval from China's MOA, leading US producers to accuse Beijing of using the new rules to protect Chinese soybean farmers. China, like many other developing countries, now faces a dilemma as to how to proceed on the further commercialization of GM crops.

Should China continue to promote its agricultural biotechnology and commercialize its GM food crops? How important are trade restrictions on GM products by other countries? What will be the impacts of alternative biotechnology policies on China's agricultural economy and trade? Answers to these questions are of critical importance for policy makers and agricultural industry.[1] The overall goal of this paper is to access the likely answers to the above issues. To achieve this goal, the paper is organized as the follows. In the next section, a general review of agricultural biotechnology development in China is provided. The impacts of Bt cotton and GM rice adoptions in China are presented in section III. The fourth section presents the model and scenarios that will be used in the impact assessments. The results on the impacts of alternative biotechnology development strategies are discussed in the fifth section. Concluding remarks are provided in the final section.

DEVELOPMENT OF GENETICALLY MODIFIED CROPS IN CHINA

Evolution of genetically modified crops

The significant progress in agricultural biotechnology was made after 1986 when China initiated a national high-tech program in March 1986 (the so called "863" program). Since then agricultural biotechnology laboratories have been established in almost every agricultural academy and major universities. There are over 100 laboratories in China involved in transgenic plants research (Chen, 2000). By 2000, there were 18 GM crops generated by Chinese research institutes, four of them have been approved for commercialization since 1997.[2] GM varieties in crops such as rice, maize, wheat, soybean, peanut and others are either in the research pipeline or are ready for commercialization (Chen, 2000).

Bt cotton is one of the most often cited examples on the progress of agricultural biotechnology in China. Since the first Bt cotton variety was approved for commercialization in 1997, the total area under Bt cotton reached nearly 1.5 million hectares in 2001, which accounted for 31 percent of China's cotton area (Figure 1). In addition, other transgenic plants with resistance to insects, disease, herbicides or that have been quality-modified have been approved for field release and are ready for commercialization. These include transgenic varieties of cotton resistant to fungal disease, rice resistant to insect pests or diseases, wheat resistant to barley yellow dwarf virus, maize resistant to insects or with improved quality, soybeans resistant to herbicides, transgenic potato resistant to bacterial disease, and so on (Huang et al., 2002a).

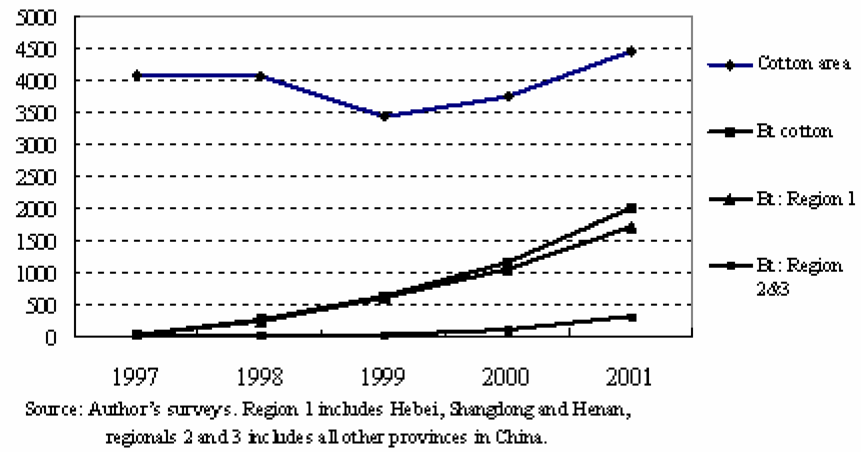

Figure 1. Cotton and Bt cotton areas (000 ha) in China, 1997-2001.

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[1] Anderson and Yao (2001) recently investigated the potential economic effects of China's adoption of GMOs based on a hypothesized 5% gain in productivity wiht GMO adoption. The results show that the effects depend to a considerable extent on the trade policy stance taken in high-income countries opposed to GMO and to liberalization of China's trade in textiles and apparel.

[2] They are Bt cotton, tomatoes with resistance to insects or improved shelf-life, a petunia with altered flower color, and sweet pepper resistant to diseases. Indeed, before these 4 crops were approved for commercialization, the first commercial release of a GM crop in the world occurred in 1992 when Chinese farmers first adopted transgenic tobacco varieties. But Chinese farmers have not been allowed to grow GM tobacco since 1995 due to strong opposition from tobacco importers from the USA and other countries.

Genetically modified cotton and rice

GM cotton and rice are two major GM crops and technologies that China has been one of leading countries in the world. The Bt gene was introduced into major cotton varieties using the Chinese-developed pollen tube pathway (Guo and Cui, 1998). Eighteen Bt cotton varieties with resistance to bollworms generated by China's public institutions and five Bt cotton varieties from Monsanto had been approved for commercialization in 9 provinces by 2002. The Biotechnology Research Institute (BRI) of CAAS recently made further breakthrough in plant disease resistance by developing cotton resistant to fungal diseases. Glucanase, glucoxidase and chitnase genes were introduced into major cotton varieties. Transgenic cotton lines with enhanced resistance to V*erticillium* and *Fusarium* were approved for environmental release in 1999 (BRI, 2000).

Research investment in GM rice has been substantial. Transgenic hybrid and conventional Bt rice varieties, resistant to rice stem borer and leaf roller were approved for environmental release in 1997 and 1998 (Zhang, 1999). The transgenic rice variety that expressed resistance to rice plant hopper has been tested in field trials. Through the anther culture, the CpTi gene and the Bar gene were successfully introduced into rice, which expressed resistance to rice stem borer and herbicide (NCBED, 2000). Transgenic rice with Xa21, Xa7 and CpTi genes resistant to bacteria blight or rice blast were developed and approved for environmental release since 1997 (NCBED, 2000). Significant progress has also been made with transgenic plants expressing drought and salinity tolerance in rice. Transgenic rice expressing drought and salinity tolerance has been in field trials since 1998. Technically, the commercialization of various GM rice is ready. However, the commercializing GM rice production has not yet been approved as the policy makers' concern on food safety, rice trade and its implication for the commercialization of other GM food crops such as soybean, wheat and maize.

ECONOMIC IMPACT OF BT COTTON AT FARM LEVEL

To examine the impact of biotechnology on various input uses and crop yield (after control for input uses) in the cotton production, Pray et al (2001) and Huang et al (2002b) used both farm budget analysis and damage control production function approach based on the production practices of Bt and non-Bt cotton farmers in 1999 in Hebei and Shandong provinces, where the bollworm has seriously damaged the local cotton production (Region I in Figure 1). These studies show that Bt cotton adopters spray 67 percent fewer times and reduce pesticide expenditures by 82 percent (Huang et al. 2002b). Because the reduction on the farmers spraying pesticide time, Bt cotton technology is also considered as a labor-saving technology. While costs of pesticides and labor inputs are reduced, seed costs of Bt varieties are higher than those of non-Bt cotton by about 100-250 percent (based on author's survey in 1999, 2000 and 2001 in 5 provinces where Bt cotton is adopted, the price difference between Bt and non-Bt cotton declined over time).

Econometrical analysis that controlled for all input differences and geographical location showed found that adoption of Bt cotton also impacts on cotton yield (Huang et al (2002b). Bt cotton contributed to about 7-15% (with an average of about 10%) of yield increase in the Hebei and Shangdong (cotton region I) in 1999.[3] These results are re-confirmed by 2 similar surveys conducted in 2000 (with additional Henan province) and in 2001 (with additional Anhui and Jiangsu provinces, cotton region II). However, new surveys in 2000-2001 also reveal that the extent of the impacts (pesticide and labor inputs and yield) decline with moving Bt cotton from the region I to region II (authors' survey).

Based on the above empirical study on Bt cotton adoption and its impacts on various inputs and yield, we hypothesize the future patterns of Bt cotton adoption will rise from 45% in 2001 to 92% in 2010 (95% in region I and 90% in both regions II and III) and its impacts on inputs and yield as those presented in Table 1. All figures in this Table represent the difference (in percentage) of input and yield between Bt cotton and non-Bt cotton.

Although the commercialization of GM rice has not been approved yet, the government has approved a number of insect, disease and herbicide resistant GM rice varieties for field trial and environmental release since the late 1990s. Interviews were conducted in the trial and environmental release areas by the authors.

[3] The range of the impacts (7-15%) reflects the different specifications of the production function models used in the regression.

The results from these interviews are used to hypothesize the impacts of GM rice commercialization on rice yield and input uses (Table 1). Our analysis also assumes that China would approve the commercialization of GM rice in 2002 and adoption rates of GM rice would reach 40% in 2005 and 95% in 2020.

Table 1. Hypothesized yield and input difference (%) between GM and Non-GM crops in 2001-2010.

	Yield by region				Input cost at national level		
	National	Region I	Region II	Region III	Pesticide	Seed	Labour
Bt cotton							
2001	5.82	8.30	5.80	3.00	-51	120	-5.1
2002	5.94	8.47	5.92	3.06	-53	120	-5.3
2005	6.30	8.98	6.28	3.25	-57	120	-5.7
2010	6.96	9.92	6.93	3.59	-67	120	-6.7
GM rice							
2002	6.00				-52	50	-7.2
2005	6.37				-56	50	-7.9
2010	7.03				-65	50	-9.1

There is a consensus that one cannot simply assume that the GM technologies imply a Hicks-neutral productivity boost as in Anderson and Yao (2001). See for example European Commission (2001) for a survey and Van Meijl and Van Tongeren (2002) for an application to Bt maize and Ht soybean technology. The productivity impact of GM technologies in crops is typically factor-biased.[4] That is, cost reductions on some of the production factors can be achieved in varying degrees. The yield increases through GM technology, for example, allow the same volume of output to be produced with less units of land. The ultimate effect on total land demand will, however, depend on the interaction of the factor saving effect (less land relative to other factors) with the expansion effect, as the total output expansion may possibly by larger than the land savings per unit of output. Similarly, the labor savings obtained from less weeding and pesticide sprayings leads to a drop of labor demand at the same level of output. Conversely, more output can be produced with the same amount of labor. The combined effects of factor-biased technical change depend on the relative cost shares of production factors and on the substitution elasticities in the production function. In addition, the general equilibrium model used in this study and discussed in the next section takes also indirect feed back effects through the demand side into account. Increased demand through lower prices in the wake of cost savings will be important determinant of the sectoral expansion.

METHODOLOGY

The economic impacts of GM cotton and rice has been done with GTAP modeling framework. This is a multi-region, multi-sector computable general equilibrium model, which is fully described in Hertel (1997). This model enables us to incorporate the detailed factor specific GM cost savings as estimated in section 3. In addition, the multi-sector framework captures backward and forward linkages between the GM crops and the using and supplying sectors. For the purposes of this paper, the GTAP database (version 5 in 1997) has been aggregated into 12 regions and 17 sectors.

The comparative static model has first been used to generate a so-called baseline projection for 2001-2010. In the second step, the impact of alternative biotechnology scenarios is assessed relative to the baseline projection for 2010. The baseline is constructed through recursive updating of the database such that exogenous GDP targets are met, and given exogenous estimates on factor endowments -skilled labor, unskilled labor, capital and natural resources- and population. For this procedure see Hertel et al. (1999), the exogenous macro assumptions are from Walmsley et. al (2000). The macro assumptions for Asia have been updated with recent information from the ADB economic outlook 2002.

The baseline projection also includes a continuation of existing policies and the effectuation of important policy events, as they are known to date.

[4] Factor biased technical change was introduced by Hicks (1932) to describe techniques that facilitate the substitution of other inputs for a specific production factor. He called techniques that facilitated the substitution of other inputs for labor "labor saving" and those designed to facilitate the substitution of other input for land "land saving".

The important policy changes are: China's WTO accession between 2002 and 2005; global phase out of the Multifibre Agreement under the WTO Agreement on Textiles and Clothing (ATC) by January 2005; and EU enlargement with CEECs.

Next to those macro- and policy assumptions, the baseline incorporates new data for the Chinese economy. We have incorporated an updated Input-Output table for China, which better reflects the size and input structure of agriculture. An important feature of the new table is an improved estimate of primary factor cost shares and crop yields. Another feature of the adjusted database is a drastic adjustment to agricultural trade data for China, which incorporates trade information for 2001. Between 1997 (the base year for GTAP version 5) and 2001 the structure and size of Chinese trade has changed dramatically, and we have adjusted the GTAP data to reflect these changes. We also incorporated econometric estimates for income elasticities for livestock products, rice and wheat (Huang and Rozelle, 1998). Given all this base information for 2001, we project the model in two steps: 2001-2005 and 2005-2010. The baseline is more fully documented in Van Meijl et al. (2002).

The baseline projection does not contain any assumptions on biotechnology developments. Three scenarios have been developed to assess the policy choices highlighted in the introductory section.[5] The first scenario is designed to study the impact of Bt cotton adoption in 2010. This impact consists of the part that is already realized in 2001 (Figure 1 and Table 1) and the assumed factor biased productivity gains during the period 2001-2010 summarized in Table 1. We assume that these cost savings affect those farmers who have adopted the GM crop varieties. That is, we weigh the productivity and seed cost estimates by adoption rates to arrive at an average impact on the cotton sector.

The second scenario adds the commercialization of GM rice during 2002-2010 to the adoption of Bt cotton. Again, we used the productivity estimates and adoption rates from Table 1. The third scenario focuses on a possible import ban on GM from China. Given that China has commercialized both Bt cotton and GM rice, an import ban on GM rice by the main trading partners is simulated. The scenario design is 'additive', by adding new elements one at a time, and we disentangle the separate effects of each new element where appropriate.

THE RESULTS

Economic impacts of commercializing Bt cotton

Table 2 shows the total impact of adopting Bt cotton and the contributions of these components to the supply price of cotton, relative to the situation without Bt cotton in 2010. The supply price will be 10.9% lower in 2010. The yield increasing and labor saving impacts of Bt cotton contribute, respectively, 7%-point and 3.3%-point to this total effect. The pesticides saving impact lowers the price with 1.7% while the higher seed price increases the supply price with 1.1%. The lower supply price increases demand. Domestic demand increases with 4.8% and exports with 58%. However, the share of exports in total demand is very low at 0.24%, and export growth does therefore contribute only mildly to the total cotton demand growth. The rise in domestic demand is almost completely caused by increased demand from the textiles sector. The lower domestic price also implies that cotton imports decrease with 16.6%, relative to the 'no-Bt' case. Trade balance for cotton will improve with 389 million USD (Table 2).

The textiles sector is the other main benefiting sector from adopting Bt cotton due to the lower supply price of cotton. Textile sector output and exports increase with 0.7% and 0.9%, respectively, while imports decrease with 0.3%. This causes the textiles trade balance to improve with 1067 million USD (Table 2). Total welfare gains 1097 million USD (not reported in Table 2).

[5] A fifth scenaron on labeling GMOs is formulated. The results show that labeling is costly to China, the welfare loss to China is about 1.3 billion USD. Due to the pace limitation, the results are not reported in this paper.

Table 2. Main sectoral effects of adopting Bt cotton (percent change, relative to situation without Bt cotton in 2010).

	Total impact	Yield increasing	Labor saving	Pesticide saving	Higher seed price
Cotton					
Supply price	-10.9	-7	-3.3	-1.7	1.1
Output	4.9	3.1	1.5	0.8	-0.5
Dom demand	4.8	3	1.5	0.8	-0.5
Exports	58	37.3	17.5	9	-5.8
Imports	-16.6	-10.8	-4.9	-2.5	3.1
Trade balance (million USD)	389	253	114	59	-71
Textiles					
Supply price	-0.3	-0.2	-0.1	0	0
Output	0.7	0.4	0.2	0.1	0
Exports	0.9	0.6	0.3	0.1	0
Imports	-0.3	-0.2	-0.1	0	0
Trade balance (million USD)	1067	670	341	155	-41

Source: model simulations

The Economic impacts of commercializing both Bt cotton and GM rice

The results incorporate both the Bt cotton effect and the GM rice effect are reported in Table 3.[6] The adoption of GM rice generates cost savings due to its yield increasing, labor saving and pesticides saving impact. If the adoption will take place according to the assumed scenario the supply price of rice will be 12% lower in 2010. Almost 8%-points can be contributed to the yield increasing impact of GM rice, 4.4% to the labor saving impact, and 0.9% to pesticides saving. The higher seed price increases the supply price with 1.1%. Despite the sharp decrease in price the output response is only 1.4%. This is due to the low income and price elasticities of domestic demand. The increase in exports is very high (67%), but the impact on output is limited since only a small portion (1.2%) of production is exported.

Table 3. Impacts of adopting GM rice (percent change, relative to situation without GM products in 2010.

	Total impact Bt cotton & GM rice	Total impact GM rice	Yield increase	Labor saving	Pesticide saving	Higher seed price
Rice						
Supply price	-12.0	-12.1	-7.8	-4.4	-0.9	1.1
Output	1.4	1.4	0.9	0.6	0.1	-0.1
Dom demand	1.1	1.1	0.7	0.4	0.1	-0.1
Exports	66.9	66.2	43.5	24.1	5.2	-5.8
Imports	-23.2	-23.4	-15.3	-8.4	-1.8	2.1
Change rice trade balance (million USD)	173.2	175.1	113.8	63.1	13.7	-15.5
Welfare (EV, million USD)	5249	4155				

Source: model simulations

[6] The interaction effects between rice and cotton are negligible. This becomes evident by comparing the first and second column in Table 3.

The commercialization of both GM crops has substantial welfare effects (Table 3). The adoption of GM rice enhances welfare in China by 4155 million USD in 2010, which is 4 times larger than in the case of Bt cotton (1097 million USD) due to the larger size of the rice sector. The impact on factor prices varies across factors. Land prices decline because factor demand is lower due to the yield increasing effect of the GM technology. Although the demand for labor decreases in both crops, the aggregate demand for labor increases as unskilled labor intensive textiles sector expanded.

Sectors that use rice or land intensively will therefore achieve the biggest cost gains and can lower their prices and expand output. Land intensive sectors such as wheat, coarse grains, cotton and other crops can use the extra land that is not necessary anymore to produce the demanded quantity of rice. Pork and poultry output will grow because they can use the cheaper coarse grains.

Although China witnesses rising exports and/or reduced imports as a consequence of rapid GM adoption, the patterns of global trade in both the textiles and garments and the rice sectors are not affected very much. Table 4 presents the changes in the regional trade balance relative to the 'no-GM' case in 2010. The impact is negligible on major rice importers such as Africa and some rice deficit developing countries in Asia as well as major rice exporters in SEA (i.e., Thailand, Vietnam and Burma). The Chinese biotechnology research strategy has in the first place concentrated on crops that are of great importance to rural livelihoods, and not on those that are important in terms of export earnings. Rice exports from China represent only a small share of world rice trade.

Table 4. Impact of adoption of Bt cotton and GM rice in China on the trade balance in various regions (year 2010, comparison against situation without GM crops).

	Rice change		Cotton change		Textiles change	
	(USD)	%	(USD)	%	(USD)	%
China	173	62	408	43	756	1
HongKong	1	0	1	-1	-25	-2
Taiwan	-1	-12	2	1	-73	-1
JapKor	-6	-2	6	1	-124	-10
SEA	-68	-14	7	0	-100	-1
OthAsia	-26	-2	-12	-19	-59	0
AusNzl	-5	-3	-51	-5	-4	0
NAFTA	-21	-4	-203	-8	-137	0
SAM	-10	-7	-6	-1	-50	-1
EU	-11	-2	1	0	-270	-1
CEEC	-2	-2	0	0	-20	-1
ROW	-23	-1	-132	-4	-67	1

The immediate impact is small on other major cotton exporters, most notably India and Pakistan, which are part of our OthAsia region. The cost savings and yield increases from Bt cotton translate into lower production cost for the Chinese textiles and garments industry, but these cost reductions are not of such orders of magnitude that other garments producers (e.g., India and Bangladesh) are affected very much. The phasing out of the multifibre agreement by 2005 is of greater importance for global textiles and garments trade than Bt cotton commercialization in China.

GMO trade ban on GM rice

In this scenario the enlarged EU, Japan, Korea and South East Asia ban GM rice from China. Technically, this is modeled as a taste shift against Chinese rice imports that reduces these countries' imports of Chinese rice to zero. Exports of GM rice from China decline substantially. Whereas an increase of rice exports volume of 67% was projected when both GM rice and Bt cotton are adopted, the trade ban results in a drop to just 5% additional exports relative to the baseline result for 2010 (Table 5). This follows immediately from the export shares in the baseline situation in 2010 (without all the biotech shocks), which amount to 21%, 8% and 9% for South East Asia, Japan-Korea and the EU27, respectively. Rice output is also declining, by 0.5 percent points (Table 5). The drop is limited, because the share of exports in production is only 1.2%. The rice trade balance deteriorates with 154 (273-19, Table 5) million USD and welfare in China decreases with 20 million USD.

Table 5 also shows the welfare effects for the banning countries. The welfare impact is negative but not substantial in these countries. The three banning regions together forego 177 million USD. The negative welfare effect is due to a negative taste or demand effect and resource misallocation.

Table 5. Impacts of GM import ban on China and other regions (comparison against situation without GM crops in 2010).

	Adopt Bt cotton and GM rice	GM trade ban
CHINA		
Rice exports (% change)	67	5
Rice output (% change)	1.4	0.9
Change rice trade balance (million USD)	173	19
Welfare (million USD)	5249	5229
OTHER REGIONS		
Japan & Korea welfare (million USD)	298	212
South East Asia welfare (million USD)	13	-33
EU-27 welfare (million USD)	-7	-52

Source: model simulations

Is it still worthwhile for China to invest in GM rice if other countries ban GM rice imports from China? The aggregate welfare measure against which the trade ban impact can be evaluated indicates that the export ban does not significantly change the benefits of adopting GM rice in China. The largest adoption gains are realized within China itself.

CONCLUSIONS

This paper uses productivity estimates for GMOs that are based on empirical micro-level data for the cotton sector and tentative experimental data for the rice sector in China. Biotechnology leads to crop specific factor biased technical change, and the results show that the distinction between yield and production factors effects is important. Factor markets for labor and land will witness different effects, depending on the type of biotechnology being adopted. The scarce land resources can be utilized more effectively with land-saving technologies. Even though labor is relatively abundant in China, the adoption of somewhat labor-saving GM crops does not necessarily lead to falling wages. This is especially the case in Bt cotton. Here, the expansion of the cotton sector itself, together with rising labor demand from the unskilled labor intensive textiles sector more than compensate for the savings in labor inputs obtained by adopting the GM crop. The use of empirical estimates that give a better indication of the magnitudes of the productivity impact of GMOs is certainly very important.

The economic gains from GMO adoption are substantial. In the most optimistic scenario, where China commercializes both Bt cotton and GM rice, the welfare gains amount to an additional annual income of about 5 billion US$ in 2010. This amounts to about 3.5 USD per person. This is not a small amount in a country, where according to the World Bank 18% of the population had to survive with less than 1$ per day in 1998.[7] Given the importance of rice for agricultural production, employment and food budget shares, the gains from GM rice adoption are orders of magnitude larger than the Bt cotton gains. The estimated macro economic welfare gains far outweigh the public biotechnology research expenditures.

Although the productivity gains for China are significant and translate to rising exports or reducing imports, the patterns of global trade in both the textiles and garments and the rice sectors are not affected very much. Our results also indicate that trade restrictions do not significantly lower the gains from biotechnology research in China. A trade ban on GM rice has only a minor effect since the portion of rice exported is very small. Our findings suggested that China should continue to promote its GM biotechnology, including commercializing its GM food crops. Policy makers should put less weight on the international dimension in making their decisions on biotechnology development.

[7] World Development Indicators. International poverty line of 1$ (PPP adjusted) in 1998.

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