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Prospects for Cultivation of Genetically Engineered Food Crops in China

Carl Pray, Jikun Huang, Ruifa Hu, Haiyan Deng, Jun Yang and Xenia K. Morin.

Abstract

Major food crops that contain genetically engineered (GE) traits cannot be legally grown in China, despite major investments in biotechnology research and despite government decisions that GE maize, soybeans, and canola are safe to import and eat. The paper uses a political economy model to analyze why GE maize and GE rice have not been commercialized in China and whether they are like to be commercialized soon. This model draws on recently completed studies of consumers' and business managers' attitudes towards the safety and the profitability of GE rice and GE maize and on new publications of the potential economic impact of these crops. Consumer opposition and the absence of competitive GE traits from Chinese companies were two major factors constraining commercialization of GE food in the past. This paper predicts that GE maize is, however, likely to be commercialized in the near future due to recent developments in GE technology, the Chinese economy, and Chinese politics.

1. Introduction [1]

China is moving from "Made in China" to "Innovated in China." (Wei et al 2017) in many sectors of the economy, but agriculture biotechnology has not made that shift. The Chinese government has invested more money in agricultural biotechnology research than any country leading to the development many genetically engineered (GE) crops with variety of different traits such as GE insect resistant cotton, rice and maize (corn) varieties, which can dramatically lower pesticide use and increase yields by limiting insect damage (Huang et al 2005). GE maize and GE rice are ready for the market. but have not been approved for commercialization (Lin et al, 2016).

In addition to GE traits that were developed in China, international corporations, universities and governments have developed a substantial pipeline of GE traits (Parisi et al 2016), many of which could be used in China to improve the incomes and health of Chinese farmers and consumers. Seventeen GE maize traits, 12 GE soybean traits, and 12 GE canola traits have been approved by the Chinese government for importation for as processing materials and subsequent consumption primarily in the forms of meat by people (USDA, 2015) . Despite this large number of options, the only foreign GE trait that Chinese farmers can legally plant is Monsanto's insect-resistant Bt cotton which was approved in 1997 and is now obsolete in the rest of the world.

With all of this agricultural biotechnology available and major investments by the Chinese government in biotechnology research, a puzzle remains: what is preventing farmers from

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planting and commercializing GE maize and GE rice. The major objective of this paper is to use a political economy model to understand why GE food crops such as Bt maize and Bt rice have not been commercialized in China and to assess whether GE food crops are likely to be commercialized soon? To analyze the past and present of biotechnology in China we use newly collected data on the perceived benefits and concerns of businessmen and consumers regarding GE crops as well as the results from new economic models of the benefits of GE crops to assess the role of key interest groups.

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The paper is organized as follows. The next section discusses the Chinese biotechnology investments and policies before 2013 when the current government came into office. Section 3 uses a political economy model to assess the importance of interest groups in the biotechnology policy making process. Section 4 then uses this interest group model to assess the new policies since 2013 and Section 5 discusses recent changes in the possible economic benefits and power of key stakeholders. Section 6 summarizes the findings of the study and speculates about whether GE rice and maize are likely to be approved in the near future.

2. Biotechnology policies before 2013

Three major goals of the Chinese government's biotechnology policy that have been consistent since the 1980s are: first, to increase the productivity of key crops and livestock so China can increase its food self-sufficiency and not be dependent on other countries for its basic food needs, and second, to build a Chinese agricultural biotechnology industry that can be a source of economic growth and compete globally. Social stability is the third goal of the government's biotechnology (and all other) policies.

To achieve the first and second biotechnology goals the central and provincial governments invested extensively in agricultural biotechnology research. Agricultural biotechnology was an important element of three special research and development programs for key industries. The first focused on applied research in nine industries of which biotechnology was one. It was designated "863" because it started in March 1986. In March 1997 the "973" program for basic research started and continued through 2006. It was followed by the 973 program in 2006 by the National Science and Technology Key Programs, a much larger government program which focused on commercializing designated technologies. The agricultural biotechnology program is called the Special Program on New Transgenic Organism Breeding, which started in 2008 and is expected to end in 2020, was one of 11 civilian programs. The goal of this program is to commercialize Chinese GE varieties of 5 crops and 3 livestock species (Hu et al., 2012). The total budget for the agricultural biotechnology program is budgeted to be US$3.8 billion (RMB 24 billion) over 12 years.

The Chinese central government also supported the development of the biotech industry by instituting regulations to assure the safety of GE food production and products and by instituting an approval process. In early 1993, the Chinese State Science and Technology Commission (SSTC) released the first set of biosafety regulations, called the "Safety Administration and Regulation on Genetic Engineering" (Chinese State Science and Technology Commission, 1993). The Ministry of Agriculture (MOA) issued the "Implementation Measures for Agricultural Biological Engineering" in 1996 (MOA, 1996). The first approvals of GE crops for commercialization took place in 1997. In 2001 the State Council decreed a new set of policy guidelines, the "Regulations on the Safety Administration of Agricultural Genetically Modified Organisms" (Huang et al., 2003). MOA also announced three new implementation regulations which covered biosafety management, imports and exports of GE foods and crops and mandatory labelling of GE food products, which took effect in March 2002 (Pray et al., 2006).

Government policies also encourage GE development and commercialization by local firms. Government scientists were encouraged to develop, patent and then license GE technology to local firms. The Special Program described above subsidized biotechnology research and commercialization by local firms. In addition, these firms were protected from foreign competition by regulations that kept out foreign technology. The biosafety regulatory system allowed the importation of foreign GE maize, soybeans and canola for processing and consumption but not for sales as seeds for food production in China. Regulations on Foreign Direct Investment (FDI) protected Chinese biotechnology firms by prohibiting research on biotechnology or commercialization GE traits by foreign firms in China. It was hoped that these delays would allow local firms to develop their own GE traits or commercialize GE traits that were developed by government research academies and universities.

The result of these policies is that in 2013 Bt cotton traits from CAAS and Monsanto that were released in 1997 are the only traits of a major field crop the Chinese farmers are allowed to grow. No new traits of GE technology for cotton cultivation has been since 1997, and no new GE technology for major feed and food crop cultivation have been commercialized. Consumers and livestock producers have benefitted from GE crops that are produced elsewhere. Most vegetable oil consumed in China is made from imported GE soybeans. Livestock are fed imported GE soy meal and GE maize

This set of agricultural biotechnology policies along with the FDI regulations kept most economic interest groups inside and outside China happy except for some biotechnology scientists and some big foreign and local biotechnology firms. Consumer remained largely in the dark with respect to any changes in their food system. Interestingly, prior to 2010, most consumers did not know they were eating oil made from GE soybeans. Studies that examined consumers' purchasing behavior found that Chinese consumers did not require a price discount to purchase the labeled GE oil (Lin et al., 2005). Farmers in the US and South America were happy because they could export soybeans and maize to China. Local seed and biotechnology firms were protected from competition with the foreign biotechnology giants. The largest Chinese group that lost money from this situation was the small maize and soybean farmers. Their potential gains from more productive GE crops were masked by government subsidies on inputs and high support prices for their crops.

After the world food price crisis of 2007 and 2008, the government in 2009 approved insect resistant rice (hereafter Bt rice) and high phytase maize (HPM) as safe for consumption and production in China. The Bt rice developed by Huazhong Agricultural University around 2000 and produced by small local seed companies and HPM was developed by CAAS and

Origin Agritech Ltd and Origin was licensed to commercialize it[2]. The government did not announce China's achievements of being the first country in the world to develop and approve GE rice or that the Bt rice could greatly reduce pesticide use making rice safer for consumers to eat and better for the environment. It also did not publicize Chinese scientists' achievement of the first GE maize that was a better animal feed and could improve the environmental impacts of livestock production. Instead the MOA quietly approved these technologies and listed their approval in official document.

Chinese consumers did not find out about government approval of GE rice and HPM maize until Greenpeace discovered and publicized it on the web in China and globally in 2010 (Greenpeace 2010). This allowed the opponents of GE crops to accuse the Chinese government of secretly approving a new type of rice that was risky for human health and for the environment. A conservative (Maoist) component of the Communist Party started using stories from Greenpeace and other global opponents of GE foods to criticize the government's decision and indirectly criticize the mainstream of the Communist Party. Some components of the Army believed the GE food was a Western plot to weaken the Chinese people and some Generals said they would not allow their troops to eat GE food and publicly opposed GE food (Yap, 2013). The soybean industry from northern China that was pushed into decline by imported GE soybeans claimed in newspapers that the regions of China that ate soy oil from GE soybeans had higher levels of cancer than regions that still used Chinese non-GE soy oil (What's on Xiamen, 2013).

At the same time, there was the breakdown of trust in the ability of the government to ensure the safety of food because of the deaths and sickness of children from contaminated milk and a regular stream of newspaper reports on food safety problems. This contributed to a firestorm of urban consumer opposition to GE food in social media starting in 2010 (Huang and Peng, 2015).

The firestorm of media attacks against GE rice in 2010 through 2012 came at a sensitive time for the government because a new government was to be chosen and put in place in late 2013. The combination of opposition in social media and uncertainty about the position of the new government on GE meant that most scientists and bureaucrats did not challenge claims about health problems related to GE food even though they were not supported by science. biotechnology

3. Benefits, awareness and influence

Table 1 summarizes the available information on the economic impacts of insect-resistant, GE rice and maize on economic interest groups and an assessment of their political influence. The first two columns of the table represent the size of the economic benefits to each group based on the projections from simulation model of the impact of Bt maize and Bt rice (Xie et al., 2017; Yang and Wang, 2014; Huang, et al 2004). The number of pluses represent the relative size of the benefits and the number of negatives represent the relation size of the losses.

2 It is considered a Chinese firm even though it is listed on the NASDAQ stock exchange because all of the founders were Chinese and its corporate headquarters are in Beijing.

The scale ranged from 1 to 4. For example, the largest benefits went to consumers in both the rice and maize models and so four pluses were assigned, while pesticide firms would lose some money due to Bt rice two negatives were assigned. Other groups who could win with GE commercialization are farmers, feed and livestock producers, Chinese biotechnology and seed firms, and government biotechnology scientists who provide biotechnology traits to private biotechnology and seed firms. Other groups beside the pesticide industry who could lose are seed companies who do *not* adopt GE traits (thus the ++/-- for the seed firms), the government breeders who license conventional hybrids to them, and some components of the food industry that export products containing rice. Comparing the beneficiaries of Bt rice and Bt maize two differences stand out: first, based on the simulation model farmers are likely to capture bigger benefits in maize than rice and second, the Chinese seed and biotechnology companies are likely to make more money in maize than rice.

The columns 3 and 4 summarize studies of each group's perception of whether they will benefit or lose with the introduction of either Bt rice or Bt maize, and includes a relative estimate of the size of their perceived benefits or losses based on surveys of consumers (Huang and Peng, 2015) and managers of agribusiness firms (Deng et al., 2015). Consumers' perception or knowledge that they could gain benefits from lower prices of grain or meat s is virtually 0but their perception of the food safety and environmental impact is very negative (Huang and Peng 2015) . Farmers' perceptions of the potential impact of GE rice and maize has not been measured by surveys, but there is evidence that it is positive. Studies on the impact of GE rice in preproduction trials at farm level indicate that insect-resistant GE rice increased yields by 0-12% and reduces insecticide use by 50-90% (Huang et al., 2008; Huang et al., 2005; Wang et al., 2010). Bt cotton is popular with farmers in regions that also grow maize and illegal Bt maize is spreading in some regions in northeast China (personal communication with Chinese seed companies, 2017). Rice farmers have little experience with Bt cotton, although rice growers in a few regions have had positive experience with the experimental Bt rice hybrids. Taken together, these observations favor positive perceptions of GE maize and possibly favorable perception of GE rice by farmers.

The perception of agribusiness groups is based on their responses to our surveys of 160 agribusiness managers in 2013-2014 by Deng et al. 2015. Maize seed and biotechnology managers expect benefits from Bt maize but are evenly divided about benefits from Bt rice. Most pesticide companies expect losses due to the reduced need for pesticides for target insects with these Bt crops. Feed companies expected benefits from Bt maize but not from Bt rice. Most of the 40 food companies expect no change but 10 expect increased profits while only 3 expect losses. Informal discussions with food companies indicate that those that had problems exporting products made from rice to Europe are very opposed to commercialization of GE rice because it would further restrict their export opportunities. A survey of scientists' attitudes shows that government biotechnology scientists are very aware of the impact of GE crops and believe that they should be developed while other scientists are skeptical (Huang et al., 2017).

The 5th and 6th columns show the authors' assessment of the ability of these groups to influence policy makers. Chinese biotechnology companies and Chinese seed companies have support from government officials who would like them to be globally competitive. Farmers, feed/livestock industries and Multinational Corporates (MNCs) have limited support from the government. The most influential groups opposing biotechnology are urban consumers, conventional breeders and scientists, food companies in rice, and pesticide groups.

An analysis of the whole table suggests some reasons why GE maize and GE rice have not been commercialized. The biggest economic winners would be consumers and farmers. Consumers do not actually see much of the economic benefits, however, because the benefits would be small to each individual, and the effects of these technologies on consumer prices is masked by other factors such as government prices policies and shifts in world grain prices. In addition, they are concerned about negative food safety and environmental impacts and have considerable political influence. Farmers could capture benefits, and many of them are aware of the benefits of these technologies, but they have little political influence in the Chinese system. Other groups who perceive big benefits are biotech companies. Among them only the Chinese biotech companies have much influence.

Comparing rice and maize, the major difference in columns 3 and 4 of Table 1 is that GE maize has fewer negatives than GE rice from consumers, the food industry, and the seed industry. In addition, the feed/livestock industry, the MNC biotechnology firms and possibly farmers have more to gain and some influence in favor of commercializing GE maize rather than GE rice.

Table 2 predicts the potential impacts of commercialization of insect resistant GE crops on government scientists as well as on the goals of the State Council. The top three rows in the rice and maize sections of Table 2 show the simulated benefits, expected benefits and our assessment of the political power of scientists. The incomes of government biotechnology scientists would improve through royalties from the GE traits they developed or profits from companies that they own, while income to government breeders of hybrids for conventional crops could decline. Nonagricultural scientists have little commercial stake in these technologies, but they do have negative perceptions of GE foods and some political clout.

The goals of the State Council suggest that they would favor commercialization of Bt maize rather than Bt rice. The bottom three rows in the rice and maize sections of Table 2 show the simulated benefits and expected benefits. The simulations showed the clear advantages of Bt maize over Bt rice in meeting government goals. Bt maize would increase food security by reducing maize imports. Bt rice would not increase food security because China is already self-sufficient and demand for rice is decreasing as incomes grow. Selling GE rice would help Chinese biotechnology companies grow in China, but it would not help them grow into globally competitive companies since GE rice production has not been approved anywhere in the world. Finally, the opposition to GE rice since 2010 already upset social stability while GE maize did not. In addition, GE maize is less likely to stir social protests because it is already being fed to animals and these animals are consumed by Chinese consumers. Unlike GE maize seeds can be sold in the Americas and a few places in Asia.

4. The Changing Policy Environment 2013 to 2016

The new Chinese government in 2013 decided to support GE agriculture, but also tried to take care of the concerns of Chinese consumers as well as some key interest groups. This led to President Xi Jinping's cautious statement of support for agricultural biotechnology at the People's Congress, December 23th in 2013 at the Central Rural Work Conference regarding GE technology, which was published in China in October 2014 (USDA, 2015):

Starting in early in 2014 several policy changes were announced. For example, in December 2014, MOA announced a development path for development of GE crops that would start with non-food crops, move to indirect food (e.g. maize and soybeans that are used for animal feed or processed food), and then food crops (Sinanews, 2014). Recently, the Chinese government announced that it would commercialize GE maize by 2020. The 2016-2020 five-year plan "recommended 'pushing forward the commercialization of new pest-resistant cotton, pest-resistant maize and herbicide-resistant soybeans" (Patton, 2016a) Pressure for another type of biotechnology policy change came from foreign agricultural biotechnology companies. They pushed their governments to bargain for reforms of FDI regulations to allow foreign firms to conduct biotechnology research and commercialize biotechnology. The pressure for this change in FDI regulations is also gaining support within the government. The Ministries of Finance and Commerce already had been pushing for change, but MOA has resisted. Now within the MOA, officials working with livestock want this change because they have constant demand for new veterinary vaccines and drugs, many of which are genetically engineered. Outside the MOA, officials from the medical field also want foreign firms to be allowed to develop GE vaccines and medicines for humans.

Finally, government officials recognize that GE traits for maize from China Agricultural University, CAAS, and private companies such as Dabeinong and Origin are effective and safe (personal communication with MOA officials at the Conference on the Safety of Genetically Modified Organisms, Beijing, China, January 16, 2015).

Despite these changes no new GE crops have been commercialized in China.

5. Recent changes expected benefits and political power

Will GE maize and rice traits be commercialized? Despite a new food safety regulatory system established in 2015, newspapers and websites regularly publish articles on food safety problems. In addition, Greenpeace and other groups regularly publicize the inability of MOA authorities to keep illegal GE rice out of supermarkets and GE maize and soybeans out of farmers' fields (e.g. Patton, 2016b). Will economic and political factors be sufficient to outweigh this perceived threat to consumers and social stability?

The crash of commodity prices and the end of the government's floor price for maize reduced local production and led to more imports. This increased the pressure on the government for more local production through technologies that would reduce input cost such as the commercialization of GE maize

New political support for the government to approve GE food crop production could come from major state-owned enterprises. Two large pesticide companies which suffered losses of pesticide sales due to Bt cotton - ChemChina and Sinochem - recently made large investments in biotechnology seed research and development. ChemChina purchased Syngenta, a leading global producer of GE crops (Syngenta 2017). SinoChem, which owns China National Seed Group, is making a major investment in biotechnology research labs in Wuhan for research on rice and maize. In addition, the agriculture branch of the state supported financial conglomerate CITIC Ltd bought Dow Chemical's Brazilian GE maize business for $1.1 billion (Reuters 2017). These changes give these major state-owned enterprises economic incentives to support commercialization of biotechnology crops in China. These firms report directly to the State Council which gives them considerable policy influence.

Farmers are putting pressure on the government to commercialize GE maize. Insect – resistant maize is being illegally cultivated in large areas northern China (Patton, 2016b; Yan, 2015) where it is protecting maize from stalk borers and out yielding conventional maize (Seed company interviews, 2016). In the past when GE seeds started to spread without the approval of the government as in the case of disease resistant papaya, the government approved them to legitimize their production. When farmers start growing superior varieties of any crop, it is very hard to stop them. In central China farmers continue to produce GE rice despite a major government campaign to eliminate it. The spread of GE maize and soybean adds more farmer support for GE maize commercialization.

Finally, the 19th People's Congress in 2017 strengthened the Community Party's leadership. They will not have to be as concerned that public attitudes about GE crops in concert with food safety concerns will threaten the political stability of the new government.

6. Conclusions

The Chinese government followed a policy of investing in and protecting the Chinese biotechnology industry to meet its goals of increasing food security and developing a globally competitive agricultural biotechnology industry. Before 2009 Chinese science was not able to develop GE traits other than Bt cotton that government regulators thought were safe and competitive with traits from foreign biotechnology companies. In 2009 the government officially recognized local Bt rice and improved quality maize as safe and ready for commercialization which created a popular backlash on social media.

The government then decided to go slow on commercialization. That decision showed that even in China, urban consumers, political opponents of the ruling party and European and Chinese non-governmental organizations that oppose GE technology can influence government policies and regulations. They slowed the commercialization of these GE food traits. Their ability to do so was based on their ability to link GE crops with food safety concerns and the need of the Chinese government to keep social stability.

Economic incentives also led to political pressure for and against the commercialization of biotechnology crops through economic interest groups. Like Europe the pesticide industry has the most to lose from the adoption of Bt crops although they have less influence than this industry has in Europe. Other groups like conventional plant breeders and seed companies also had something to lose. They were happy to support the decision of MOA not to commercialize Bt maize and Bt rice.

In recent years several changes increased the probability that GE maize will be approved by the government. GE maize from Chinese scientists is ready to be commercialized. Farmers have made their wishes clear by planting unapproved GE maize extensively in northern China. Agribusiness SOEs, which previously had an incentive to oppose GE cultivation, are buying foreign biotech companies and financing local biotech research. Finally, the current government has emerged from the recent Party Congress with their power enhanced reducing their concern about political problems if they commercialize GM maize. These changes suggest that the government will go ahead with GE maize production in 2020 or soon after that.

References

Anonymous, 2013. Contrary to popular belief. *Nature Biotechnology*. 31(9), 767-767.

Chinese State Science and Technology Commission, 1993. Safety Administration and Regulation on Genetic Engineering. http://www.cqjlpwsj.gov.cn/html/zcfg/ggw-sfg/13/09/114.html (Accessed 20 November 2016).

Deng, H., Hu, R., Huang, J., Pray, C., Jin, Y., 2015. Managers' Attitudes and Impact of the stakeholders on the Commercialization of Genetically Modified Crops. Presented at the Friendship Hotel at the Conference on the Safety of Genetically Modified Organisms, Beijing, China, January 16, 2015.

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., ... & Toulmin, C, 2010. Food security: the challenge of feeding 9 billion people. *Science*. 327(5967), 812-818.

Greenpeace 2010. China Okays Bt Rice, Doesn't Tell Public. http://www.greenpeace.org/eastasia/news/stories/food-agriculture/2010/GE-rice-China-passed/

Hu, R., Cai, J., Huang, J., & Wang, X, 2012. Silos hamstring Chinese plant biotechnology sector. *Nat. Biotechnology.*, 30(8), 749-Huang J, Hu R, Rozelle S, Pray CE, 2008. Genetically modified rice, yields, and pesticides: assessing farm-level productivity effects in China. *Economic Development and Cultural Change.* 56:241–63.

Huang J, Hu R, Rozelle S, Pray CE 2005. Insect-resistant GE rice in farmers' fields: assessing productivity and health effects in China. *Science*. 308:688–90.

Huang, J. and Peng B., 2015. Consumers' perceptions on GE food safety in urban China. *J. Integr. Agric.,* 14(11), 2391–2400

Huang, J.,Peng B., and Wang, X, 2017. Scientists' attitudes toward agricultural GM technology development and GM food in China. *China Agricultural Economic Review*. 9(3), 369-384.

Huang, J., Hu, R., van Meijl, H., van Tongeren, F., 2004. Biotechnology Boosts to Crop Productivity in China: Trade and Welfare Implications. *J. Dev. Econ.,* 75(1), 27-54.

Huang, J. , Wang, Q., 2003. Agricultural Biotechnology Development and Policy in China, *AgBioForum*. 5(4),122-135.

ISAAA 2017 ISAAA's GM Approval Database. http://www.isaaa.org/gmapprovaldatabase/

Kuzma, J, 2016. Reboot the debate on genetic engineering: arguments about whether process or product should be the focus of regulation are stalling progress. *Nature*, 531(7593), 165-168.

Lin, Q., Hallerman, E., Peng Y., Li, Y., 2016. Development of Bt Rice and Bt Maize in China and Their Efficacy in Target Pest Control. *Int J of Mol Sci 17*, 1561-76. doi:10:3390/ijms17101561

Lin, W., Somwaru, A., Tuan F., Huang, J., Bai, J., 2005. Consumers' Willingness to Pay for Biotechnology Foods in China and Washington, D.C., *Paper prepared for presentation at the 9th International Consortium on Agricultural Biotechnology Research (ICABR)* in Ravello, Italy, July 6-10, 2005.

Ministry of Agriculture (MOA), 1996. Implementation Measures for Agricultural Biological Engineering. http://www.moa.gov.cn/ztzl/xumugb/99-3-4.htm (Accessed 20 November 2016).

Ministry of Agriculture (MOA) 2016a. MOA holds press conference on GMO. http://english.agri.gov.cn/new-s/dqnf/201604/t20160414_168130.htm (Accessed 13 October 2017)

Ministry of Agriculture (MOA),, 2016b. Measures for the Administration of Safety Assessment of Agricultural Genetically Modified Organisms. http://www.gov.cn/gongbao/content/2017/content_5174526.htm (Accessed 15 July 2017).

Ministry of Agriculture (MOA) 2016c. Seed Law of the People's Republic of China. http://www.moa.gov.c- n/fwllm/zxbs/xzxk/bszl/201405/t20140527_3917992.htm (Accessed 15 July 2017).

Parisi,C., Tillie, P., and Rodríguez-Cerezo. E. 2016 The global pipeline of GM crops out to 2020 *Nature Biotechnology* Volume 34 Number 1 January 2016

Patton, D, 2016a. China backs GEO soybeans in push for high-tech agriculture. Reuters Aug 10, 2016. http://www.reuters.com/article/us-china-GEo-idUSKCN10L0NX (Accessed 10 September 2017).

Patton D, 2016b. Chinese farmers are illegally growing GEO corn: Greenpeace. Reuters. http://www.reuters.com/article/us-china-GEo-corn-idUSKBN0UK06B20160107 (Accessed 10 September 2017).

Payne, J. M, 2016, Standing up for scientific consensus. *Nature biotechnology.* 34(1), 23.

Pray,C.E. Huang,J., Ma,D., and Qiao, F. 2001.Impact of Bt Cotton in China. *World Development* Vol.29, No.5, pp.813-825

Pray, C.E., Ramaswami, B., Huang, J., Hu, R., Bengali, P. and Zhang, H., 2006. Costs and enforcement of biosafety regulations in India and China. *International Journal of Technology and Globalization*, 2(1-2), 137-157

Reuters 2017 China's CITIC Agri Fund buys Dow corn seed assets for $1.1 billion https://www.reuters.com/article/us-dow-divestiture-citic/chinas-citic-agri-fund-buys-dow-corn-seed-assets-for-1-1-billion-idUSKBN19W2NS. (Accessed Oct. 26, 2017)

Sinanews, 2014. MOA talked about the development of GEOs: non-food crop, indirect food and food crops. http://news.sina.com.cn/c/2014-12-05/1106-31250088.shtml (Accessed 15 July 2017).

State Council, 2016. Thirteenth Five-Year National Technology Innovation Planning. http://news.xinhuanet.com/tec h/2016-08/09/c_129215081.htm (Accessed 15 July 2017).

Syngenta 2017 ChemChina and Syngenta closing event in Basel, June 27, 2017 https://www.youtube.com/watch?v=JrP0pgHnwpA downloaded November 29, 2017

USDA, 2014. China-People Republic of Planting Seeds Annual 2014. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Planting%20Seeds%20Annual%202014_Beijing_China%20-%20Peoples%20Republic%20of_7-18-2014.pdf (Accessed 15 July 2017).

USDA, 2015. China: Agricultural Biotechnology Annual. http://gain.fas.usda.go-v/Recent%20GAIN%20Publications/Agricultural%20Biotechnology%20Annual_Beijing_China%20-%20Peoples%20Republic%20of_12-31-2014.pdf (Accessed 15 July 2017).

Wang, Y., Zhang, G., Du, J., Liu, B., & Wang, M, 2010. Influence of transgenic hybrid rice expressing a fused gene derived from cry1Ab and cry1Ac on primary insect pests and rice yield. Crop Protection, 29(2), 128-133.

What's on Xiamen, 2013. Chinese researchers link GE soybean to cancer, downloaded October 18, 2016. http://www.whatsonxiamen.com/wi- ne_msg.php?titleid=2320 (Accessed 15 July 2017).

Wei,S.J., Xie, Zhang, X., 2017 From "Made in China" to "Innovated in China": Necessity, Prospect, and Challenges. *Journal of Economic Perspectives* 31(1), 49-70.

Xie,W., Tariq Ali, Qi Cui, Jikun Huang, 2017. Economic impacts of commercializing insect-resistant GM maize in China. *China Agricultural Economic Re*view. 9(3), 340-354.

Yang, J. and Wang X.. 2014, Impacts of GE Maize and Rice in China on Food Security, Economic Development and Environment: Assessments based on General Equilibrium Model. *Presented at the Department of Agricultural, Food and Resource Economics*, *Rutgers University*, September 17, 2014.

Yap, C.W. 2013. It's China vs. China in Genetically Modified Food Fight. *Wall Street Journal,* September 3, 2013. http://blogs.wsj.com/chinarealti me/20- 13/09/03/its-china-vs-china-in-GEo-food-fight/ (Accessed 15 July 2017).

Yan, L., 2015. Many farmers in Northeast China grow GE soybeans despite official ban. *Global Times,* 2015-09-07. www.globaltimes.cn/content/940855.shtml (Accessed 15 July 2017).

Zhang, X., 2015. International Soybean Growers' Alliance lobby China to speed up the approval of genetically modified varieties. http://finance.sina.com.cn/chan-jing/cyxw/20150424/005922031867.shtml (Accessed 15 July 2017).

Table 1. Summary of predicted relative stakeholders' economic benefits and losses with commercialization of GE rice and GE maize and their relative political influence in commercialization decision-making for GE rice and GE Maize

Stakeholders	Economic Impacts from simulations*		Awareness/Expectation of impact from surveys*		Political influence*	
	Rice	Maize	Rice	Maize	Rice	Maize
MNC biotechnology/seed/chem	+	+	+++	++++	+	+
Chinese biotechnology firms	+	++	++++	++++	++	++
Chinese seed firms	+/-	++	+/-	+	+/-	+
Insecticide cos	- -	- -	- - -	- - -	-	-
Farmers	+++	+++	++	++	+	+
Feed/livestock	++	++	0	+	0	+
Food industry	+/-	+/-	- - -	- -	- -	-
Chinese consumers' economic gain	++++	++++	0	0	- - -	-
Consumer (food safety)	+	0	- - - -	-	- - -	- - -
Consumer (Environment)	+	+	- - -	-	- - -	-

*Sources: The "Impacts" columns are based primarily on simulations from Xie et al 2017 and Yang and Wang 2014. The awareness/expectations columns are based on the surveys of consumers by Huang and Peng 2015 and agribusinesses by Hu et al 2015. Political influence columns are based on the authors' interviews and experience participating in the debates on biotechnology in China.

Table 2. Predicted relative benefits and loses to government stakeholders and to government leadership upon commercialization of GE rice and GE maize.

Stakeholders	Impacts from simulations*	Awareness/Expecte d impact*	Political influence*
RICE			
Government biotechnology scientists	++	+++	+++
Govt. conventional breeders	+	- - -	- -
Govt. other scientists	0	- -	- -
State Council goals			
Food security	0	+	na
Chinese biotechnology industry	0	0	na
Social stability	+	- - -	na
MAIZE			
Government biotechnology scientists	++	+++	+++
Govt conventional breeders	+	- - -	- -
Govt other scientists	0	- -	- -
State Council goals			
Food security	+++	+++	na
Global biotechnology industry	++	+++	na
Social stability	+	0	na

*Source: The "Impacts" column is based primarily on our simulations by Yang and Wang 2014. The other two columns are our judgements based on the authors' interviews and experience in the debates on biotechnology in China. NA means not applicable because they are the group that is being influenced.