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Scientists' attitudes toward agricultural GM technology development and GM food in China

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Abstract
Purpose – Previous studies have mainly focused on public opinions regarding genetically modified (GM) technology and GM food. The purpose of this paper is to assess scientists' attitudes on whether China needs to develop its national agricultural GM technology and their willingness to buy GM food.
Design/methodology/approach – A stratified sampling method was used to select and interview 806 scientists from six major agricultural universities and 20 research institutes under two national academies in China in 2013. Based on these data, the authors use both descriptive statistics and multivariate regression analysis to examine scientists' attitudes toward agricultural GM technology and food, using GM soybean oil as an example of GM foods.
Findings – The survey results show that nearly three-quarters of scientists agree that China needs to develop its agricultural GM technology, but their attitudes differ largely. Only 29 percent of scientists are willing to buy GM soybean oil, similar to urban consumers (25 percent) in China. The knowledge of biology is extensive for some scientists but varies significant among scientists and correlates positively with their attitudes toward agricultural GM technology and GM soybean oil. Younger and male scientists with higher professional titles, and those involved in GM research are more in favor of China's GM technology compared to other scientists. Female scientists, scientists with lower professional titles, those that have never engaged in GM research or are from non-agricultural scientific disciplines are less willing to buy GM soybean oil. Interestingly, their low willingness to buy GM soybean oil is inconsistent with the fact that it is the most common edible oil in China.
Originality/value – This study is the first to examine scientists' attitudes toward GM technology and food in China. The results of this study contribute to understanding the current debates on GM technology and the relevance of research, based on the willingness to buy GM food, for decision making regarding the commercialization of GM technology.

Keywords China, Knowledge, GM food, GM technology, Scientists

Paper type Research paper

1. Introduction
Public debates regarding genetically modified (GM) technology and food have taken place for more than two decades. These debates range from environmental and sustainable impacts (Qaim, 2009; Brookes and Barfoot, 2013; Macnaghten and Carro-Ripalda, 2015; National Academies of Sciences, Engineering, and Medicine (NASEM), 2016; Qiao *et al.*, 2016) to health impacts (Gaskell *et al.*, 1999; Kuiper *et al.*, 2001; Domingo and Bordonaba, 2011; Huang *et al.*, 2015; NASEM, 2016), and socioeconomic impacts as well as ethical issues (Qaim and De Janvry, 2005; Schurman and Munro, 2010; NASEM, 2016). While the pros and cons of genetic modification have been debated for decades, these debates are unlikely to be solved soon (Fuglie and Toole, 2014; NASEM). On the other hand, the GM crop acreage has been expanding since the initial wide use of

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GM technology in 1996; the accumulated acreage of GM crops in the past 30 years (1996-2016) has reached 2.1 billion hectares (ISAAA, 2016).

The debates have significantly influenced the attitudes of the whole society toward GM technology. Although GM crops have been considered as one of the fastest adopted crop technologies (ISAAA, 2016), only 26 countries had planted GM crops by 2016. The impacts of the debates have obviously influenced the public's and scientists' attitudes toward GM technology and food, which further affects the national decision on whether to commercialize GM technology (Paarlberg and Pray, 2007; Paarlberg, 2008; Gruère and Sengupta, 2009).

Previous studies regarding attitudes toward GM technology and food have mainly focused on the public or the consumers. Most studies show that consumer acceptance of or willingness to buy (WTB) GM foods is not high (Bredahl, 2001; Bonny, 2003; Wolf *et al.*, 2012; Krishna and Qaim, 2008; Frewer *et al.*, 2013), and has declined over time in many countries (Huang *et al.*, 2006; Krystallis *et al.*, 2007; Huang and Peng, 2015; Runge *et al.*, 2015). For example, in China, the percentage of consumers who perceived GM food as unsafe for consumption increased by more than 30 percent during 2002-2012 (Huang and Peng, 2015). Even in the USA, the proportion of Americans who believe foods made from GM crops pose a serious health hazard to consumers increased from 27 percent in 1999 to 48 percent in 2013 (Runge *et al.*, 2015). Regarding the factors affecting consumers' perceptions of GM food, one of major conclusions is that consumers often lack knowledge regarding GM technologies and therefore, this situation calls for scientists to participate actively in the popularization of the GM technology. However, this assumes that scientists are much more aware of GM technologies and therefore, would have more favorable attitudes toward GM technology and food than consumers would. Do these inferences hold in reality?

Unfortunately, very few studies have been conducted that examine scientists' attitudes toward GM technology and food. Moreover, these studies are mostly conducted in developed countries. For example, a survey of the public's and scientists' views on science and society, conducted by the Pew Research Center in 2015, shows that most scientists (88 percent) from the American Association for the Advancement of Science (AAAS) state that "it is generally safe to eat genetically modified foods compared with 37% of the public who say the same." A survey conducted in four European countries in 2013 found that while both consumers and experts agree that consumers lack relevant knowledge, experts have a higher acceptance of GM food than consumers (Krystallis *et al.*, 2007). Another study by Aleksejeva (2014) based on a survey of experts from 23 European Union (EU) member states in 2013 shows that 21 percent of experts are in favor of using GM food in general, while 55 percent consider that GM food should be evaluated on a case by case basis (or that every single GM food should be analyzed individually). The percentage of experts that do not support the consumption of GM food is only 18 percent. While EU experts are supportive toward GM food, they are more concerned about the cultivation of GM plants due to concerns that GM crops pose an environmental risk.

Despite several recent studies regarding scientists' attitudes toward GM technology and foods as mentioned above, no study has been conducted in developing countries that aimed to understand the different attitudes of scientists toward GM technology and food. What are scientists' attitudes toward GM technology and food in developing countries? Are their attitudes consistent for both GM technology and food? Do different scientists have different opinions regarding either GM technology or GM food? If yes, why? Is there a relationship between scientists' knowledge and their attitudes toward GM technology or GM food? Answering these questions is important because of the roles of various scientists in public debates and their influence on public and private decision making regarding agricultural GM technology.

This study aims to provide answers to the above research questions and uses China as a case study. China is an interesting case because the country has invested substantially in agricultural GM technology research, but the only major GM field crop that has been extensively grown in China is cotton. While there are many reasons for the lack of GM crop commercialization in China, the general negative attitudes of the public toward GM food is critical. Recently, China launched the popularization of GM science and technology and called for scientists to take a more active role in this initiative. Based on the scientists' survey conducted in this study, it was found that while most scientists are supportive of China's agricultural GM technology development, a majority are not willing to buy GM food. Moreover, the attitudes toward either GM technology or GM foods differ among scientists, which can largely explained by their personal characteristics, research fields, and disciplines. Their biological knowledge is not very impressive, although it is much better than that of consumers. Better biological knowledge among scientists leads to a much higher acceptance of GM food; however, their average acceptance is not much higher than that of the general public. The results of this study have several research and policy implications.

The remainder of this paper is organized as the follows. Section 2 introduces the sampling strategy and data used in this study. The results from the descriptive and multivariate analyses are presented in Sections 3 and 4, respectively. The last section concludes this study with the research and policy implications.

2. Sampling strategy and data

2.1 Sampling strategy

Sampling strategy: selecting institutions. Selecting an appropriate sample to examine the scientists' attitudes toward agricultural GM technology and food is a challenge because large differences exist in terms of their affiliations and disciplines as well as their knowledge of biotechnology. To systematically deal with these issues, we first set up the following three criteria to select institutions for the survey: institutions from both academies and universities; institutions directly or indirectly related to agriculture; and institutions comprising both natural and social scientists. Based on these criteria, three types of institutions were selected: the Chinese Academy of Agricultural Sciences (CAAS), the Chinese Academy of Sciences (CAS), and the leading national and regional agricultural universities. CAAS represents the national research institutions focused on agriculture, CAS represents the national research institutions focused on basic research, and the universities represent institutions focused on both education and research. Selecting these three institutions also implies that we target the sampled institutions in the upper tiers of research academies and agricultural universities in China.

Research institutes under the CAAS and CAS and the agricultural universities were sampled as follows. Under the CAAS, all research institutes are related to agriculture, including both natural and social sciences; we chose ten representative research institutes (Table AI). They include three crop research institutes; two livestock and veterinary research institutes; and one research institute each from the fields of biotechnology, plant protection, quality standard and testing technology, environment and sustainable development, and agricultural economics. Under the CAS, there are 316 research institutes, among which 20 of them conducting research in either agriculture-related fields or policy research are considered. Within these 20 institutes, we randomly selected ten institutes for this study. These institutes cover the fields of plants and animals, genetics and biology, resources and the environment, nutrition and health, psychology, and strategic and policy research (Table AI). Six agricultural universities were selected based on their national and regional representation. They are China Agricultural University (a national university), South China Agricultural University (a representative of South China), Huazhong Agricultural University (a representative of

Central China), Nanjing Agricultural University (a representative of East China), Northwest Agriculture and Forestry University (a representative of Northwest China), and Northeast Agricultural University (a representative of Northeast China).

Sampling strategy: selecting scientists. We aimed to have 800 samples (scientists) in total, with 100 samples from each of the CAAS, the CAS, and the six agricultural universities. This sampling strategy implies that a weight of 12.5 percent each was given to CAS (mainly basic research) and CAAS (mainly applied research), and 75 percent to the agricultural universities (both basic and applied research), which also roughly represents the number of agriculture-related scientists between the basic and applied fields in China.

Within each of the CAAS, the CAS, and the six agricultural universities, we applied a stratified proportional and randomly sampling approach to select the scientists. For the CAS and CAAS, we selected the samples in five steps. First, we obtained a list of all scientists with titles equivalent to the following three titles from each of the ten selected institutes: full professor, associated professor, and assistant professor or below. Second, we calculated the number of the scientists chosen for the survey (n_i) from each of the ten institutes by 100 times a weight (N_i/N) that equals to the total number of the scientists in each institute (N_i) divided by the total number of scientists in all ten institutes (N). Third, using the total number of scientists assigned to each institute (n_i), we allocated the number of scientists by their titles (equivalent to full professor, associate professor, and assistant professor or below) based on the percentage of scientists under each title in its institute. Fourth, with the number of samples for each title in each institute, we randomly selected scientists from each title group. If any of the selected scientists was not available during our survey time, a replacement was randomly selected from the group with the same title from the same institute. Finally, the list of sampled scientists with their personal code numbers was provided to a staff member in each institute who coordinated with us in conducting the survey.

The sampling method of choosing the scientists in agricultural universities was also based on a stratified proportion random sampling approach. In each university, we performed the following five steps to select the scientists. First, we obtained the total number of full-time professors, associate professors, and assistant professors or below in the whole university (M) and in each department (M_i). Second, we calculated the number of samples for survey in each department ($m_i = 100 \times M_i/M$). Third, we allocated the number of scientists for the survey from each department by the title (full professor, associate professor, and assistant professor or below) based on the percentage of scientists under each title within its department. Fourth, with the number of samples for each title, we randomly selected scientists from each of the three groups. A replacement was randomly selected from the same title group if any of selected samples was not available during our survey period. The final step that involved coding personal numbers and conducting the survey was coordinated by the Division of Scientific Research in each university.

The sampling and survey were conducted in 2013. The surveyed scientists were anonymized by giving each of them a code number. The final number of samples (806) was slightly larger than the planned survey number (800), with 102 from CAS, 103 from CAAS, and 601 from the six universities (Table AI). This slight difference was mainly due to the rounding error when allocating the actual number to each institute within the CAS or CAAS, and each department within two universities. Among the surveyed samples, 214 were professors, 302 were associate professors, and 290 were assistant professors or below, they accounted for 27, 37, and 36 percent of the total sample, respectively.

2.2 Survey method and data

To conduct the survey, research staff from the Center for Chinese Agricultural Policy of the CAS and collaborators from the CAAS and the six universities supervised the data collection process to guarantee the quality of the survey. The entire survey process was anonymous to ensure that the respondents provide authentic, reliable, and objective responses. The survey was carried out by either face-to-face interview or e-mail.

The questionnaire includes several blocks of questions; the data from the first three blocks are used in this study. The first block addresses the respondents' characteristics and disciplines as well as whether the respondents participated in any GM-related research. The second block comprises questions about the respondents' attitudes toward GM technology development and GM food. Regarding the attitudes toward GM technology development, this study analyzes the answers of the following question: is it necessary to develop agricultural GM technology in China? Each respondent was asked to choose one of the three answers that best describes his/her position: 1 = yes, 2 = no, or 3 = do not know. Regarding the attitudes toward to GM food, this study analyzes the scientists' WTB GM soybean oil. Each scientist was asked to choose one of the following answers: 1 = yes; 2 = no; 3 = do not know. We chose GM soybean oil for this study because it has been sold in China since the early 2000s (Zhong *et al.*, 2002). Since nearly all imported soybeans are GM soybeans and used for processing soybean oil for food consumption, we estimate that Chinese people consumed about 12 million tons of GM soybean oil in 2013, which increased to about 16 million tons in 2016.

The third block is a basic biology knowledge quiz, with the following five statements related to GM technology and one statement regarding the relationship between parents' blood type and their children's:

(1) GM tomatoes contain genes, but an ordinary tomato does not contain genes.

(2) If a person eats GM fruits, his/her genes would change.

(3) An animal's genes cannot be inserted into plants.

(4) Cherry tomatoes are a GM food.

(5) Hybrid rice is GM rice.

(6) If one parent's blood type is "A" and the other's is "B," their children could be type "O."

For each statement, the respondent was asked to select one of three answers: 1 = right; 2 = false; 3 = do not know[1].

3. Descriptive analysis

3.1 Overview of the sample

The sample covers a wide range of scientists. The scientists surveyed belong to different age cohorts with 60 percent males and 40 percent females (column 1, Table I). The scientists with full professor and associate professor titles account for 27 and 37 percent, respectively. It is important to note that 94 percent of them have either a doctorate (70 percent) or a master's degree (24 percent) (Table I). Nearly one-fourth (24 percent) of the scientists had participated in agricultural GM research. In terms of disciplines, the scientists were divided into four broad categories: social science, science (or general science), engineering, and agricultural science. Agricultural science is further broken down into plant, animal, and other agriculture; the latter includes all agricultural science fields that are not included in plant and animal sciences. The survey data show that the percentage of scientists from different disciplines ranges from 8 percent in science, to 14 percent in animal agriculture, and about 20 percent in each other discipline (social science, crop and other agricultural sciences) (Table I).

3.2 Scientists' attitudes toward GM technology development in China

In general, most scientists support the development of agricultural GM technology in China (column 2, Table I). The survey results show that a majority of scientists (76 percent)

	Sample share (%)	Percentage of scientists who consider the technology Necessary	Not necessary	No idea	Willing to buy GM soybean oil
Average	100	76	13.5	10.5	29
Age (years)					
⩽ 35	25	78	11	11	30
35-40	24	68	18	14	29
40-45	19	82	12	5	25
> 45	32	77	12	11	30
Gender					
Male	60	81	11	8	33
Female	40	70	17	14	23
Professional titles					
Assistant professor or below	36	68	18	14	27
Associate professor	37	81	11	8	29
Full professors	27	81	9	9	36
Education level					
Bachelor or below	6	72	7	22	30
Master	24	68	19	14	23
Doctor	70	80	12	8	36
Employers					
CAAS	13	94	3	3	51
CAS	13	82	9	9	37
Universities	75	72	16	12	28
Participated in GM research					
Yes	24	97	1	2	52
No	76	69	18	13	22
Disciplines					
Social science	18	65	15	20	28
Science	8	59	21	20	17
Engineering	20	67	20	13	18
Agriculture: plant	19	87	11	2	35
Agriculture: animal	14	89	6	5	42
Agriculture: others	21	84	10	6	41
Willing to buy GM soybean oil					
Yes	29	94	3	3	100
No	71	69	18	14	0

Note: Total sample is 806 for all variables except for age (794) and willing to buy soybean oil (803)
Source: Authors' survey

Table I.
Scientists' attitudes on the necessary of developing agricultural GM technology and willing to but GM soybean oil in China

considered the development of agricultural GM technology as necessary for China, while less than 14 percent considered it to be unnecessary, and nearly 11 percent of them have no opinion (row 1, Table I). While there is no clear relationship between age and favorable attitudes toward agricultural GM technology development in China, a statistically significant difference is observed between male and female scientists (rows 6-7). The higher support of agricultural GM technology by male rather than female scientists is consistent with their WTB GM food (1/3 for male and 1/4 for female, not shown in Table I). This result is also consistent with consumers' or general public attitudes toward GM food. For example, Huang and Peng (2015) show that male consumers tend to trust GM food as safe for consumption more than their counterparts do.

A larger variation in the support for agricultural GM technology development is observed for the scientists from different institutions and the nature of their work in terms of engagement in GM research and scientists belonging to different disciplines. For example, 94 percent of scientists from CAAS state that it is necessary to develop agricultural GM technology in China compared with 82 percent of the scientists from CAS and 72 percent from universities who reached the same opinion (rows 8-10, Table I). More support from CAAS' scientists may be explained by their familiarity with agricultural technology, including agricultural GM technology. Interestingly, the support for agricultural GM technology development from scientists from agricultural universities is 22 percent (94−72 percent) less than those from CAAS. The most significant differences in the scientists' support for agricultural GM technology occur among scientists participating in different research and from different fields. For example, for scientists who have participated in GM research, nearly all (97 percent) of them support agricultural GM technology development, compared to 69 percent of those who did not participate in GM research. Table I also shows that the disciplines of scientists are important. The lowest support is observed from those in science (59 percent), and relatively low support from those in social science (65 percent) and engineering (67 percent) (Table I). Conversely, these scientists have much higher opinions of "Not necessary" or "No idea" regarding whether China should develop its GM technology. Among agricultural scientists, the proportion supporting agricultural GM technology development ranges from 84 percent (other fields) to 89 percent (animal) (in the bottom part of Table I). The data presented in the last two rows of Table I also suggest that 94 percent of the scientists willing to buy GM soybean oil support China's agricultural GM technology development, that is, their opinions regarding GM food are positively related with their attitudes toward China's GM technology development.

3.3 Scientists' WTB GM soybean oil

Regarding scientists' WTB GM soybean oil, our survey indicates a seemingly contradictory phenomenon. As mentioned earlier, we focused our analysis on GM soybean oil since it is a common edible oil, consumed by general consumers for nearly 20 years. Moreover, GM soybean oil has been labeled since 2002. However, our survey results suggest that most of scientists are not willing to buy GM soybean oil in China. Scientists willing to buy GM soybean oil account for only 29 percent (last column, Table I).

Low WTB GM soybean oil is observed for nearly all scientists except those who work more in agricultural fields. For example, the percentage of scientists who are willing to buy GM soybean oil in four age cohorts is no more than 30 percent (Table I, last column). On average, despite female scientists and the scientists with higher professional titles having a higher WTB GM soybean oil, their percentages do not exceed 36 percent. The percentage of scientists willing to buy GM soybean oil exceeds 50 percent only for those who are from CAAS (51 percent) or who participate in GM research (52 percent). While not reported in this study, based on the same survey data, Peng (2014) shows that scientists' WTB GM food does not differ between GM soybean oil and GM rice (also about 29 percent), which is not significantly different from the general public's attitude toward GM food in urban China surveyed in 2012 (Huang and Peng, 2015).

3.4 Scientists' biological knowledge and attitudes toward GM technology and food

The literature often claims that the low WTB GM food by the general consumers is partially due to the lack of their knowledge on biological science and technology (e.g. Huang *et al.*, 2006; Allum *et al.*, 2008), however, can the Chinese scientists' low acceptance of GM food be explained by their scientific knowledge? To answer this question, we analyze the survey results on the number of right answers to the six statements presented earlier. Table II shows that the similarity in attitudes toward GM food between scientists and consumers cannot be explained by differences in their level of biological knowledge. The three of six quizzes regarding GM technologies were answered by both scientists, in this study in 2013, and consumers in an urban consumer survey in 2012 (Huang and Peng, 2015); the percentage of scientists with the right answers for each quiz is much higher than that of the consumers. On average, 70 percent (average of 91, 66, and 71 percent) of the scientists have the right answers, which is more than twice that of the urban consumers (36 percent).

While there is no comparable information available from other studies regarding scientists' knowledge of biology or GM technology, Table II also shows that scientists should not be expected to know everything. For the six basic biological knowledge questions presented in Table II, on average, about 18 percent of them answered with "Don't know" (see footnote of Table II) and 17 percent of them had wrong answers (100−65−18 = 17). This result can be explained by the wider coverage of scientists' fields and their specialization. While not presented in Table II, the order of scientists with the right answers ranged from low to high based on their disciplines as follows: social science, engineering, science, and agriculture.

While the overall results regarding scientists' biological knowledge are not impressive, given that they are scientists, the range of quiz scores is interesting. Table III shows that the average scientist has 4.14 right answers for the six questions and about two-thirds of scientists (68 percent) can provide right answers for at least four questions (Table III). On the other hand, only 10 percent of scientists had the right answers to all six questions and 12 percent had the right answers to no more than two (row 1, Table III).

Table II.
The percentage of scientists and urban consumers with right answers of quizzes and their willing to buy GM soybean in China

	Scientists (this study)	Urban consumers (Huang and Peng, 2015)
(1) GM tomatoes contain genes, but ordinary tomato does not contain genes	91	41
(2) A person eats GM fruits, his/her genes would be changed	66	50
(3) Animal's genes cannot be inserted into plants	71	22
(4) Cherry tomatoes is GM food	48	na
(5) Hybrid rice is GM rice	85	na
(6) If one of parent's blood is A and the other is B, their children could be O	54	na
Average of above quizzes	65	36
Willing to buy GM soybean oil	29	25

Notes: na, not available. For scientists, the percentages of them with answer of "Don't know" for the six quizzes in the order presented in this table are 6, 31, 19, 34, 8, and 9 percent, respectively, with average of 18 percent
Source: Authors' survey

Table III.
Percentage of scientists' attitudes on agricultural GM technology, willing to buy GM food, and their scores of GM technology knowledge quiz

	Number of questions with correct answers					
	⩽ 2	3	4	5	6	Willing to buy GM soybean oil
Share of sample	12	20	28	30	10	
Agri. GM technology						
Necessary	58	68	78	85	88	36
Not necessary	19	17	12	11	8	6
Do not know	24	15	10	5	4	10
Willing to buy GM soybean oil	8	20	27	42	43	29

Note: Average of right answers is 4.14
Source: Authors' survey

Despite scientists having a better knowledge of biology than the general public, scientists do not have a greater acceptance of GM food. Examining the relationship between scientists' knowledge and their attitude toward agricultural GM technology and GM food reveals several interesting findings (Table III). First, there is a positive relationship between knowledge and attitudes toward agricultural GM technology development. For example, among scientists with only two or less correct answers, only 58 percent of them support agricultural GM technology development in China, and 19 percent of them consider this technology as unnecessary for the country; they also have the highest response (24 percent) of "Don't know" answers (column 1, Table III). As the number of correct answers increase, that is, moving from left to right in Table III, the attitudes toward supporting China's agricultural GM technology development increases, and the number of "not necessary" or "Don't know" responses decreases. For scientists with all six correct answers, 88 percent of them state that it is necessary to develop China's agricultural GM technology. Second, the knowledge of biology is also positively related to the scientists' WTB GM soybean oil (the last row, Table III). For example, the percentage of scientists who are willing to buy GM soybean oil increases from 8 percent for scientists with two or less correct answers to 43 percent for the scientists with all six correct answers. Obviously, the scientists' knowledge can affect their attitudes toward GM foods.

Table III also reveals that there is a positive relationship between scientists' attitudes toward supporting agricultural GM technology and their WTB GM food. While on average, only 29 percent of scientists state that they are willing to buy GM soybean oil, the percentage increases to 36 percent for scientists that support agricultural GM technology, and is only 6 percent for the scientists who do not consider this technology necessary for China (last column, Table III).

4. Econometric model and empirical results

4.1 Econometric model

To identify the factors that affect the scientists' attitudes on whether China should develop its agricultural GM technology, we develop an econometric model for empirical estimation. To do this, we focus on those factors whose impacts can be identified rather than all the relationships that have been discussed in the previous section. For example, while there is strong relationship between scientists' attitude regarding developing China's agricultural GM technology, their biological knowledge, and their WTB GM food, the causality cannot be examined in this study because the surveyed data do not allow us to do so. Therefore, our econometric analysis only includes those variables in our data that are largely exogenous to the scientists' attitudes on China's agricultural GM technology development and their WTB GM soybean oil. The model in general form is specified as follows:

$$Y_i = f\left(P_j, Z_j\right) + \varepsilon_j$$

The dependent variable Y_i has two alternative specifications, the first is the *i*th scientist's attitude regarding the necessity of developing agricultural GM technology in China, and the second is his/her WTB GM soybean oil. It has a value of 1 if he/she considers GM technology necessary (or is willing to buy GM soybean oil), and 0 otherwise. P_j represents the personal characteristics of the scientist, including his/her age (years), gender (male = 1; female = 0), professional title, education level, and affiliation. Professional title includes two dummy variables, associate professor and professor (or full professor); their comparison base is assistant professor or below. Education level also includes two dummy variables, master's degree and doctorate; those with qualifications lower than a master's degree form the comparison base. Two dummy variables for the scientists from CAS and the universities are included to examine whether the attitudes of scientists from CAS and the universities differ from those of the scientists from CAAS. Z_j represents the nature of the respondent's work or field. We use two sets of alternative variables. The first variable, participation in GM research, represents whether the scientist has participated in agricultural GM research (1 = yes; 0 = no). Although this variable could be exogenous to scientists' attitudes toward agricultural GM technology, there is also concern that a scientist who supports China's agricultural GM technology now might have sought to participate in GM research. Therefore, we estimate the model without this variable and replace it with a set of dummy variables that represent the discipline of the scientists, including science, engineering, agriculture (plant), agriculture (animal), and agriculture (others); the scientists in these disciplines are compared with those in the social sciences.

The samples used in the regressions are as follows. To estimate the scientists' attitude toward the necessity to develop China's agricultural GM technology, we exclude those samples with the response of "Don't know." Thus, we analyze all scientists with clear attitudes on the issues examined. The overall results are largely consistent if we also include the samples that cannot make a decision (or with a "Don't know" answer). To estimate the scientists' WTB GM soybean oil, we eliminate 14 samples with "Don't know" answers. A binary probit model is used for empirical estimation.

4.2 Empirical results

Table IV shows the results regarding scientists' attitude toward whether China should develop its agricultural GM technology. In general, the model performs well. More than two-thirds of the variables have statistically significant coefficients, and the estimated coefficients for scientists' personal characteristics are robust between alternative specifications (columns 1 and 2, Table IV).

The estimated results show that younger and male scientists tend to support the development of China's agricultural GM technology. The estimated coefficients (−0.005 to −0.006, statistically significant at the 5 percent level, row 1 of Table IV) suggest that, after controlling for other factors, age with additional years can lower the probability of

Table IV. Estimation results of scientists' attitudes on the development of agricultural GM technology, probit model

	Attitudes (1 = necessary; 0 = not necessary) (1)	(2)
Respondent's characteristics		
Age	−0.005** (−2.11)	−0.006** (−2.33)
Male	0.036 (1.62)	0.050* (1.88)
Associate professor	0.102*** (3.84)	0.114*** (3.66)
Professor	0.094*** (2.73)	0.120*** (2.96)
Master degree	−0.130* (−1.83)	−0.169** (−2.02)
Doctor degree	−0.089* (−1.84)	−0.106* (−1.82)
CAS	−0.026 (−0.41)	−0.069 (−0.93)
Universities	−0.085** (−2.04)	−0.117*** (−2.60)
Participate in GM research	0.154*** (4.51)	
Discipline		
Science		−0.060 (−1.08)
Engineering		−0.044 (−1.11)
Agriculture: plant		0.034 (0.88)
Agriculture: animal		0.077* (1.91)
Agriculture: others		0.021 (0.51)

Notes: All numbers in parentheses are robust *z*-statistics. The number of sample in regression is 712, excluding those with the response of "Don't know" and without providing their ages. *,**,***Significant at 10, 5 and 1 percent levels, respectively supporting China's agricultural GM technology development by 0.5 percent. We expect more support for this novel technology from the youth since they live in a modern society with relatively more rapid technological changes, as compared to that of the elderly. On the average, the male scientists have a 5 percent higher probability of supporting agricultural GM technology than female scientists (row 2 and column 2), but their estimated coefficient is not statistically significant when we do not control for their disciplines (column 1, Table IV).

The impacts of scientists' professional ranking and education level on their support for agricultural GM technology differ and are even opposite. Controlling for education and other variables, we find that scientists with professional titles of associate professor or full professor have a higher probability (about 9 to 10 percent in column 1 and 11 to 12 percent in column 2, Table IV) of supporting agricultural GM technology than scientists with professional titles of assistant professor or below. While more support for agricultural GM technology development from scientists with higher professional ranking might be understandable since they may have better scientific knowledge regarding GM technology, such as GM crops, the estimated negative and statistically significant coefficients for scientists with master degrees and doctorates is surprising. Further examination of the estimated coefficients for scientists with master degrees (−0.130 in column 1 and −0.169 in column 2) and doctorates (−0.089 in column 1 and −0.106 in column 2) reveals that the difference between their coefficients is statistically significant. Specifically, the support for agricultural GM technology ranks as follows: scientists with master degrees, doctorates, and others (with or below bachelor degree). Further investigation is required to understand why scientists that have completed a graduate program have less support for China's agricultural GM technology than those who have not.

The estimated results also show that the affiliation of scientists is important (Table IV). Controlling for the impacts of other factors, scientists from universities are less in favor of developing China's agricultural GM technology, while there is no difference between the scientists from CAS and CAAS. One possible explanation is that universities have both education and research missions, while the primary task of the scientists from CAS and CAAS is research and development. They can benefit from the expansion of China's agricultural GM technology by conducting more research in this area.

Among all variables, participating in GM research has the most significant impact on scientists' attitudes toward supporting agricultural GM research in China. The estimated coefficient for the variable of participated in GM research is 0.154 and statistically significant at 1 percent (Table IV). This result can be explained by several reasons. First, they have a better understanding of the role of agricultural GM technology than those who have not participated in any GM-related research program. For example, our survey shows that, for the scientists who participated in agricultural GM research, 81 and 63 percent of them agreed that GM technology can improve China's food security and agricultural production environment, respectively. While the corresponding numbers are 49 and 31 percent, respectively, for those who did not participate in the GM research. Second, obviously, the scientists involved in agricultural GM research can also benefit from China's agricultural GM technology development through more research funding and the commercialization of GM technology in the future.

Although a large variation in the attitudes of scientists from different disciplines toward agricultural GM technology development is observed based on the descriptive analysis presented in the previous section, the results of the multivariate regression do not fully support this. Controlling for the personal characteristics of scientists such as age, gender, professional titles, education level, and affiliation, we do not find any significant relationship between scientists' attitudes toward GM technology development and their disciplines, except for agricultural scientists who work in animal fields (column 2, Table IV). The general insignificance of the estimated coefficients of the different attitudes for all scientists, except for agricultural scientists within the animal sector, presented in Table I is largely due to their personal characteristics. Compared to other scientists, animal agricultural scientists support for GM technology in our sample might be explained by the wider and longer history of use of modern biotechnology in veterinary fields.

The results of estimating the scientists' WTB GM soybean oil are presented in Table V. Nearly half of the estimated coefficients are statistically significant. The regression results show that there is no evidence of the relationship between scientists' ages or education and their WTB GM soybean oil, while there is a general negative relationship between the scientists' ages or education and their support for agricultural GM technology development in China. This comparison also suggests that while the younger and more educated scientists have more support for GM technology, there is no difference in their WTB GM foods.

Regarding the scientists' personal characteristics, significant coefficients are found for the variables of gender and professional ranking. The positive and significant coefficients (0.068-0.076, rows 2, Table V) of the male variable suggest that, controlling for other factors, male scientists have about a 6.8 to 7.6 percent greater probability of buying GM soybean oil than the females. Compared to assistant professor, the associate professor has about 9 percent and professors have about 11 to 13 percent higher probability of buying GM soybean (rows 3 and 4). The above results are consistent with their positions on supporting agricultural GM technology in China, as presented in Table IV.

We find little evidence of the effect of scientists' affiliations on their WTB GM soybean oil. Only the scientists from CAS in column 1 in Table V have a statistically significant and positive coefficient. However, after controlling for the impacts of disciplines, the coefficient of the CAS variable becomes insignificant (column 2, Table V).

Table V also shows that the scientists' research works and disciplines have significant effects on their WTB GM soybean oil. Participation in GM research has the most significant effect on the scientists' WTB GM soybean oil. The estimated coefficient is statistically significant at the 1 percent level in China, and the magnitude is 0.283 (column 1, Table V), which is almost equal to the average percentage of scientists who are willing to buy GM

Table V. Estimation results of scientists' willing to buy GM soybean oil, probit model

	Willing to buy (1 = yes; 0 = no)	
	(1)	(2)
Respondent's characteristics		
Age	−0.004 (−1.19)	−0.004 (−1.37)
Male	0.068** (1.98)	0.076** (2.22)
Associate professor	0.095** (2.07)	0.086* (1.87)
Professor	0.105 (1.62)	0.129** (1.99)
Master degree	0.032 (0.40)	0.034 (0.42)
Doctor degree	0.013 (0.16)	0.018 (0.23)
CAS	0.141** (2.03)	0.066 (1.00)
Universities	0.001 (0.03)	−0.035 (−0.70)
Participate in GM research	0.283*** (6.57)	
Discipline		
Science		−0.028 (−0.37)
Engineering		−0.016 (−0.29)
Agriculture: plant		0.153*** (2.59)
Agriculture: animal		0.225*** (3.42)
Agriculture: others		0.179*** (3.00)
Samples	792	792

Notes: All numbers in parentheses are robust *z*-statistics. The number of sample used in regression is 792, excluding the 14 samples without data on ages and/or willing to buy GM soybean oil. *,**,***Significant at 10, 5 and 1 percent levels, respectively soybean oil (29 percent). After controlling for the personal characteristics of scientists, scientists from agricultural disciplines have a much higher WTB GM soybean oil than other scientists, including those from social science, general science, and engineering (column 2, Table V).

5. Conclusion and discussion

Based on a large sample of the scientists' survey, this study shows that most scientists support the development of China's own agricultural GM technology, which is similar to the results of studies in the US and in EU countries (Krystallis *et al.*, 2007; Pew Research Center, 2015; Aleksejeva, 2014). However, our study contributes to existing literature by analyzing the heterogeneity of scientists and their attitudes toward GM technology.

We find that the scientists' attitudes toward this novel technology differ based on age, gender, professional position, educational level, affiliation, and type of research they are engaged in. We also find that the scientists' knowledge regarding basic biology is strongly related to their views on whether it is necessary for China to develop its own agricultural GM technology. While the conventional view on popularization of science, including GM science and technology, is that it is targeted at the public, this study suggests there is also room for improvement for scientists.

Moreover, this study shows that scientists' WTB GM food differs significantly from their attitudes to support agricultural GM technology development. Less than 30 percent of scientists are willing to buy GM soybean oil, and there is no difference in WTB between different GM foods (e.g. GM rice). Compared with the general public or consumers, the higher scientific knowledge of scientists does not lead to their higher acceptance of GM food, although better knowledge is positively associated with their WTB GM food within scientist community. The characteristics of scientists in terms of gender, professional position, research focus, and disciplines have significant impacts on scientists' WTB GM food.

If the lack of WTB GM food would reflect the scientists' actual behavior in the real world, it raises several research and policy questions: why do scientists support agricultural GM technology development but not trust the food derived from GM crops? Does their support for agricultural GM technology arise from their personal interest in conducting research and technological innovation? Alternatively, do they believe that China should be one of the leading countries for this important and novel technology? Can we trust the food generated by scientists who support research and development of a novel technology but do not want to consume it themselves?

If the lack of WTB GM food world not reflects the scientists' actual behavior in the real world, the approach commonly used in the literature and this study to examine the public and scientists' subjective opinions on GM foods may be unsuitable, that is, WTB studies may not shed much light on consumers (including scientists as consumers) actual purchasing behaviors. More than 10 million tons of GM soybean oil are sold annually with compulsory labeling in the Chinese market, and have been consumed by most, if not all, consumers since the early 2000s. Of course, it is possible that some scientists are not aware that the food derived from GM crops is available in the market; however, the probability of this should be low. WTB may differ from actual purchasing behaviors since the latter involves considering the price rather than whether the food contents the materials from the GM crops. The lack of any difference in WTB between GM soybean oil and GM rice that has not been in the market is even more unreasonable, which further questions the suitability of the WTB survey approach, and requires further research.

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Note

1. There are no GM cherry tomatoes in China. Except for the last statement (6), all other statements are false.

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(The Appendix follows overleaf.)

Appendix

Institutions and universities	Samples
Chinese Academy of Agricultural Sciences (CAAS)	103
The Institute of Plant Protection	16
The Institute of Cotton Research	18
The Institute of Biotechnology Research	8
The Institute of Rice Research	9
Harbin Veterinary Research Institute	9
Institute of Quality Standard and Testing Technology for Agro-Products	3
Institute of Environment and Sustainable Development in Agriculture	8
Institute of Agricultural Economics and Development	10
Oil crops Research Institute	8
Livestock Research Institute	14
Chinese Academy of Sciences (CAS)	102
Institute of Genetics and Developmental Biology	10
Institute of Zoology	11
Institute of Botany	19
Institute for Nutritional Sciences, Shanghai	5
Institute of Subtropical Agriculture	6
Research Center for Eco-Environmental Sciences	12
Institute of Geographic Sciences and Natural Resources Research	21
Institute of Science and Technology Policy and Management Science	3
Guangzhou Institutes of Biomedicine and Health	8
Institutes of Psychology	7
China Agricultural University	100
Nanjing Agricultural University	100
Huazhong Agricultural University	100
South China Agricultural University	102
Northwest A&F University	100
Shenyang Agricultural University	99
Total	806

Table AI. The sample distribution of scientists by affiliation

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