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Perception and Attitude toward GM Technology among Agribusiness Managers in China as Producers and as Consumers

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Abstract: China is one of the biggest consumers of genetically modified (GM) products, importing maize, soybeans and canola, and producing GM cotton. The cultivation of GM food crop, however, is still not permitted. Many studies argue that consumers' attitude toward GM food safety is a major barrier to GM food crop production in China. Recent studies suggest that special interest groups such as biotechnology scientists with an economic interest in biotechnology are more supportive of the technology than groups with nothing to gain. Others believe that agribusiness groups influence the debate about GM food production. This is the first study that examined agribusiness managers' attitudes toward GM biosafety and their support for GM crop production. The sample was 160 firms in the seed, pesticide, feed and food processing industries. We found most agribusiness leaders are concerned about GM food consumption and oppose GM crop production. Using regression models, we found business managers' attitudes toward GM crop cultivation are more supportive if they expect to profit, if they are already using GM crops in their firm or are doing research on GM crops.

Keywords: genetically modified foods; perception and attitude; industries; managers and consumers; China

1. Introduction

Genetically modified (GM) crops are spreading rapidly all over the world including China. As one of the world's leading countries in the application of GM technology in agriculture, China began growing insect-resistant cotton in 1997, which accounted for 5.8% of the total cotton planting area in that year [1]. In 2015, more than 7 million small farmers in China planted 3.7 million hectares of *Bacillus thuringiensis* (Bt) cotton and the adoption rate reached 96% [2]. The economic benefits of Chinese farmers from Bt cotton reached US$ 1 billion in 2016 alone and US$ 19.6 billion during 1996–2016 [3]. A National Scientific and Technological Innovation Plan issued by the government in 2016 proposed to strengthen research on GM crops and promote the industrialization of new varieties of Bt cotton, Bt corn, and herbicide-tolerant (HT) soybeans over the next five years [4]. This was the first time that the government outlined specific GM crops to be developed during a specific time period. Chinese government has also invested billions of RMB (hundreds of million dollars) in research to develop the agricultural biotechnology industry. In February 2016, the China National Chemical Corporation (ChemChina), a wholly state-owned corporation, made a $43 billion offer to purchase Syngenta, the Swiss biotech, pesticide and seed giant.

Despite the large benefits and heavy R&D investment, the use of GM products in foods remains controversial in China. Less than 30% of Chinese consumers and scientists say they are willing to

buy GM products [5,6]. To push for the use of biotechnology, the government has published positive reports about GM technology and enacted policies to mitigate objections from key stakeholders, such as initiating an online blog on "hot topics" and "authority concern of genetically modified organisms" to disclose relevant laws and regulations and establishing regulatory priorities for GM crops that are proposed for deregulation [7]. However, these measures have not had a substantial impact. Stakeholders, such as pesticide and some food firms, strongly oppose the cultivation of biotechnology food crop because of concerns that they would lose sales [8–11]. If their profit regarding GM products could be changed, these stakeholders' attitudes might change [12]. Agribusiness firms play an important role in shaping the biotechnology policy. For examples, pesticide firms were influential in preventing widespread cultivation of GM food crops in Europe [9,13]. Thus, a better understanding of private agribusiness perception and attitudes toward the application of GM technology are of considerable importance.

A series of studies on attitudes towards GM technology application in agriculture have focused on consumers, farmers [5,14–22] and a few other stakeholders [23,24]. There is a dearth of research on agribusiness managers' perception and their choices on GM technology. Sarno and Malgeri Manzo [25] found that Italian agricultural firm managers are concerned about safety of GM food and the impact of GM crops on human health. Deng et al. [26] investigated the impact of Chinese agribusiness managers' acceptance of GM foods on firms' R&D investment decision and lobbying activities but failed to analyze managers' dual identity as user of GM technology and consumer of GM products. The agribusiness managers have some features that set them apart from the average consumers of food [27]. The main difference is that agribusiness managers have to decide whether their firms will sell GM seeds and chemicals that are complementary to GM seeds or use GM products in the food and feed that they sell. Negative rumors/reports regarding GM technology are widespread in China [28]. Chinese agribusiness managers might be influenced by this information and tend to be against GM foods like Chinese consumers [5]. On the other hand, some agribusiness managers, such as those in feed industry, might take firm profitability more into consideration and might be more willing to support the adoption of GM crops in China.

With these considerations in mind, this study sought to shed further light on Chinese agribusiness managers' perception as well as their attitudes toward GM technology as both consumers and producers, focusing on the extent to which managers' attitudes as producers are associated with economic factors influencing firm profitability as well as managers' acceptance of GM foods as consumers.

2. Literature Review

2.1. Consumers and Farmers

Consumer decisions play a vital role in which products will come into the market and shaping the government and agribusiness firms' strategies or policies [29,30]. Consumer demand for GM foods is an important determinant of the demand for GM technology by farmers [14]. An extensive range of research on consumers' demand or attitude toward GM foods have been conducted. One recent survey performed in Europe shows that over 50% of consumers are opposed to GM foods [15]. Greece has the highest proportion of opponents of GM foods with more than 80% [16]. Most young European consumers have never or rarely consumed GM foods, and many of them discourage people from consuming GM foods [31]. A survey by the Pew Research Center in United States shows that only 37% of American consumers think GM food is safe for human consumption [32]. In developing countries such as Mexico, although most consumers believe that GM crops play an important role in increasing agricultural production, less than half of them consider GM foods acceptable for production and consumption [17]. In China, the share of consumers who perceive GM foods as safe for consumption decreased from 37% in 2002 to 13% in 2012, whereas the proportion of those who perceived GM foods as unsafe increased from 13% in 2002 to 45% in 2012 [5].

Farmers, as the principle beneficiaries of agricultural biotechnology, also have different attitudes towards the deployment of GM technology. Zilberman et al. [33] classified American and European farmers into three types: crop growers, livestock operators, and organic growers. Crop farmers tend to plant GM corn and soybean because it can increase crop yields and respond to the increasing demand for meat that depends on corn and soybean to feed livestock in China and other countries as well. However, they are reluctant to plant GM wheat because they worry that it would be a problem to export it to Europe [34]. Livestock operators are usually the major supporters of GM crops as it reduces livestock production costs. Organic farmers are a group of leading opponents although GM technology may be beneficial to them [33]. In Europe, over one third of farmers in Spain, France and Hungary would be willing to cultivate GM crops if they were allowed [35]. Over 60% of farmers in the UK stated that they would consider growing GM oilseed, rape and sugar beets when they were approved by the government [36].

2.2. Agribusiness Firms

There are a few studies investigating the agribusiness firms' opinion of GM technology. The seed and biotech industries tend to support development and implementation of GM technology [37]. In India, for example, seed and biotech companies can make substantial profits from commercialization of GM crops by increased sales and profit margin as well as receiving government funding for biotech R&D investments and maintaining monopoly power to capture the profits from licensing GM strains to other seed companies [38]. The pesticide industry often tends to be opposed to GM crops. European agrichemical companies lost some market share with the introduction of GM pest-control products [9], while chemical firms in India experienced lost sales up to 70% after GM cotton was introduced in 2002 [8,39].

The results of studies on attitudes toward GM technology are mixed for the food industry. The U.S. food industry tends to support GM corn and soybeans [40,41]. European food manufacturers and retailers have chosen to remove GM foods from the food supply chains and to focus on non-GM foods [42]. Food industry and retailers in Brazil, especially the French-owned hypermarkets, have reluctantly embraced GM crops due to the concern that environmental groups may spearhead marketing campaigns against GM products, although producers in Brazil are very positive of GM crops [43].

The scarce literature examining the perceptions of the animal feed industry suggests that feed industry supports GM products and biotechnology. Lucht [29] found that over 95% of food animals consumed GM feed in the U.S. As a major importer of GM products, the European Union (EU) mainly uses GM feed in the livestock and poultry sectors. Many European importers and feed manufacturers have criticized the EU policy against GM crops because of the possibility of supply shortage, price increases for feed, and loss of competitiveness for EU livestock and poultry sectors [10]. Boccaletti et al. [44] showed that, due to the strict policy on GM technology in Europe, dealing with GM and non-GM inputs for feed and food supply chains became a big challenge, which might result in increased segregation costs and reduced international competitiveness of some sectors.

2.3. Determinants of Interest Groups' Attitudes

Given that interest groups can have an important impact on policies on the use of GM technology, the reasons behind their attitudes are important to supporters and opponents of GMOs and have been explored by many studies [14,27,45]. One reason that can explain the level of consumers' acceptance of GM foods is risk perceptions and preferences [45,46]. When consumers think that GM foods are risky to human health and the environment, the possibility of their acceptance of GM foods is much lower [14]. Since activists have been spreading information about the potential risk of GM technology on social media [47], trust in the food system and regulatory institutions and knowledge of GM technology are important factors affecting consumers' attitudes about GM foods [48–51]. Consumers' attitudes

toward GM foods are also influenced by social characteristics, such as age, gender, education, and individual's scientific background [46,52–54].

Economic factors are also considered an important factor influencing farmers' and agribusiness firms' attitudes toward GM technology. Breustedt, Müller-Scheeßel and Latacz-Lohmann [53] examined the farmers in Germany and indicated that farmers' adoption decision of GM crops is influenced by the profit expectations. Apel [8] revealed that chemical firms extremely oppose the adoption and promotion of GM crops due to a sharp drop of sales in pesticides after the introduction of GM cotton. Graff and Zilberman [9] showed that economic factors may explain European chemical firms' resistance to agricultural biotechnology. Bett et al. [55] showed that Kenyan food processing and marketing firms' acceptance of GM foods in the food industry were influenced by their perception risk and benefit perception.

3. Materials and Methods

3.1. Firm Survey

We aimed at capturing Chinese agribusiness managers' perception and attitudes toward GM crops as consumers and as producers as well as the major reasons behind their attitudes. Our empirical analysis thus relied on upon a convenient survey data in the food, feed, chemical and seed industries, including 50 seed, 53 chemical, 40 food and 17 feed firms. (Food and feed firms are likely to use GM products as raw material, such as GM corn or soybean, so they are two major players relevant to GM technology. Chemical firms sell products relevant to GM crops, such as glyphosate or pesticide, and seed firms are associated with GM technology since they sell GM seeds, such as GM cotton seed. Thus, chemical and seed firms are major players too.) The sample might be not a typical representative of agribusiness firms associated with GM technology in theory, but it included many large-size firms in different industries. The 50 seed firms are among top 70 seed firms, which are identified based on firm net income and revenue, sales per year, revenue per year, R&D investment, self-R&D on breeding and number of production base. The 53 chemical firms include 7 firms listed on the Chinese stock markets and 13 firms among top 100 chemical firms in China. The 40 food firms are good representative firms of grain and cooking oil in the food processing industry, including three firms listed on the Chinese stock markets. The 17 feed firms are representative of mid-sized feed firms in Eastern China. Thus, despite the small sample size, the dataset is a good sample to analyze Chinese agribusiness firm managers' perception of GM technology and attitudes toward GM crops. Due to difficulties of getting access to high-level managers in different industries, stakeholder representatives were identified with the assistant of key informants, including officials in the Ministry of Agriculture (MOA), the industry association and the local agricultural departments, as well as a representative who used to work in the university (see more details about the survey in [26]).

The survey questionnaire consisted of 66 questions in two parts, including firm-level and manager-level questionnaires. The firm-level questionnaire included information about firms' R&D investment, how firms' profits would change if China commercialized new GM crops (gain, lose, no change, and not sure), whether they supported the adoption of GM crops and other questions about firm characteristics such as firm size, whether firms own patent, etc. The manager-level questionnaire included messages about firm managers' perceptions of GM products, attitudes toward GM foods, acceptance of GM products produced by foreign firms, and managers' characteristics such as gender, age and education background.

In total, 160 agribusiness firms in the food, feed, chemical and seed industries were interviewed. Most of the sampled firms were not state-owned enterprises, particularly in the feed and chemical industries (Table 1). The average firm size, measured by registered capital, was approximately 1.2 million RMB ($180,000 U.S. dollars equivalent). Due to trade secret concerns, a substantial number of companies were reluctant to provide their sales data. Only half of the firms (n = 81) provided complete answers to the questions about their sales, and the average sales of the firms that did provide

us with such information was 2839.8 million RMB ($426.3 million U.S. dollars equivalent). None of the seed firms provided their sales data. According to data provided by an official in the MOA, the average sales of the top 70 major seed firms, including the 50 surveyed firms, is 352.6 million RMB ($53.5 million U.S. dollars equivalent). In terms of the number of employees, the largest firms were food firms, followed by chemical and seed firms, and then feed firms.

Table 1. Descriptive statistics of Variables.

Variable	Description	Mean	Std. Dev.
Attitude toward GM foods	Average scale of Five-point Likert scale: 1 (strongly opposed), 2 (opposed), 3 (neutral), 4 (supportive) to 5 (strongly supportive)	2.47	1.16
Attitude toward Adoption	1 = if respondents are supportive of adoption of GM crops; 0 = otherwise	0.34	0.47
Biology or related major	1 = if respondents major in biology or related major; 0 = otherwise	0.28	0.45
Age (years)	Respondents' age	39.44	9.36
Male	1 = if respondents are male; 0 = otherwise	0.87	0.34
Work time (years)	How long respondents have worked	16.22	10.26
Bachelor's or above	1 = if respondents got the bachelor degree or above; 0 = otherwise	0.69	0.46
CEO	1 = if respondents are CEO of the firms; 0 = otherwise	0.36	0.48
State-owned	1 = if respondent firms are state-owned; 0 = otherwise	0.16	0.37
Registration capital	Firms' registration capital (million RMB)	11.48	18.12
No. of employees	Firms' employees (person)	921	317
Food firm	1 = if respondent firms are food firm; 0 = otherwise	0.25	0.43
Feed firm	1 = if respondent firms are feed firm; 0 = otherwise	0.11	0.31
Seed firm	1 = if respondent firms are seed firm; 0 = otherwise	0.31	0.46
Gain	1 = if firms expected to benefit from adoption of GM crops; 0 = otherwise	0.31	0.46
Loss	1 = if firms expected to lose money from GM crop adoption; 0 = otherwise	0.18	0.38
Mixed	1 = if firms expected to both benefit and lose money from adoption of GM crops; 0 = otherwise	0.05	0.22
Not sure	1 = if firms were not sure of profit change from adoption of GM crops; 0 = otherwise	0.19	0.39
No decrease in oil purchases	1 = if firms expected consumers would not reduce the purchase of GM soybean oil; 0 = otherwise	0.36	0.48
No idea regarding changes in oil purchases	1 = if firms have no idea of consumers' behavior on purchasing soybean oil; 0 = otherwise	0.23	0.42
No decrease in rice purchases	1 = if firms expected consumers would not reduce the purchase of rice; 0 = otherwise	0.39	0.49
No idea regarding changes in rice purchases	1 = if firms have no idea of consumers' behavior on purchasing rice; 0 = otherwise	0.24	0.43
No decrease in pork purchases	1 = if firms expected consumers would not reduce the purchase of rice; 0 = otherwise	0.34	0.47
No idea regarding changes in pork purchases	1 = if firms have no idea of w consumers' behavior on purchasing pork; 0 = otherwise	0.23	0.42
Biotechnology products	1 = if firms sell GM products; 0 = otherwise	0.44	0.50
Biotechnology R&D	1 = if firms conduct biotech R&D; 0 = otherwise	0.28	0.45

Firm managers were in their thirties or early forties, were predominantly male, and had more than a decade of work experience. A significant proportion of the respondents were high-level senior managers: 54%, 47%, 30% and 19% were CEOs in the seed, feed, food and chemical industries, respectively. Some of the respondents were managers in the R&D department. More than 80% of the respondents in the seed, feed and chemical industries had earned a bachelor's degree or above, and 55% in the food industry had earned such a degree. Most respondents neither majored in biology or related fields, nor had competent biotechnology knowledge, with an exception of managers in the seed industry.

3.2. Research Framework

This study depended upon and extended previous studies by either analyzing consumers' attitudes' determinants, or focusing on capturing different industries' attitudes/ perceptions. It was

based on agribusiness managers' dual identity as consumers and producers to explore the determinants of agribusiness managers' attitudes toward GM foods as consumers and the cultivation of GM crops as producers. The connection between attitudes and perceptions were also examined.

3.2.1. The Choice Model of Managers' Attitude as Producers

Choice modeling has been widely used to analyze consumers' attitudes toward GM foods and farmers' choices between adoption and non-adoption of GM crops [56–61]. Following the modeling approach on farmers' choices of GM crops in Qaim and De Janvry [60] and Breustedt, Müller-Scheeßel and Latacz-Lohmann [53], this study modeled firm managers' decision of whether to support the adoption of GM crops as producers in a random utility framework. A firm manager will support the adoption of GM crops when utility with agricultural biotechnology is at least as great as without it, that is

$$U(GM, Eco_1; X) \geq U(NGM, Eco_0; X) \tag{1}$$

where *GM* indicates biotechnology and *NGM* the non-GM or conventional alternative. Eco_1 and Eco_0 are economic factors associated with commercial adoption of GM crops and non-adoption of GM crops, respectively. X is a vector of manager and firm characteristics, including age, gender, ownership, firm size, etc. The utility inequality can be written as

$$V(GM, Eco_1; X) + \varepsilon_1 \geq V(NGM, Eco_0; X) + \varepsilon_0 \tag{2}$$

The utility of firm managers as producers based on a choice (whether they support or oppose the adoption of GM crops in China) varies across individuals, as expressed below:

$$v_i = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 EXP + \boldsymbol{\beta}_2 FDA + \boldsymbol{\beta}_3 FAC + \boldsymbol{\beta}_4 MAC \tag{3}$$

where *EXP* represents the factors characterizing firm profit expectation associated with GM products, biotechnology R&D, and the experience of selling GM products; *FDA* is a measure of the managers' degree of personal acceptance of GM products as consumers; *FAC* is a vector of factors reflecting a firm's characteristics; and *MAC* includes other variables that capture managers' socioeconomic characteristics, such as educational background, age, and gender. The model explanatory variables are explained in Table 1. In this setting, the probability that individual k will select option i is

$$P(Supportive_k = i) = \frac{\exp[\mu v_i]}{\sum_{j=0}^{1} \exp[\mu v_j]} = \frac{\exp[\mu(\boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 EXP + \boldsymbol{\beta}_2 FDA + \boldsymbol{\beta}_3 FAC + \boldsymbol{\beta}_4 MAC)]}{\sum_{j=0}^{1} \exp[\mu(\beta_0 + \beta_1 EXP + \beta_2 FDA + \beta_3 FAC + \beta_4 MAC)]} \text{ED} \tag{4}$$

where $Supportive_k$ equals one when the manager supports the adoption of GM crops in China; otherwise it is zero.

3.2.2. The Model of Managers' Attitude as Consumers

Managers were asked to indicate their attitudes toward seven types of GM foods on a Likert scale ranging from 1 (strongly opposed) to 5 (strongly positive), including tofu made using transgenic soybeans, edible oil made using transgenic soybeans, pest-resistant transgenic rice, GM rice with improved nutrition, insect- or disease-resistant transgenic rice, food containing GM corn ingredients and pork from pigs that were fed GM feed (such as corn). The attitude toward any one of these products cannot fully reflect their attitudes toward GM technology. For example, 62% of managers are against insect- or disease-resistant transgenic wheat, whereas only 45% are opposed to pork raised on GM feed (Table 2). Deng et al. (2017) [26] tried to take managers' attitudes toward GM foods as a dummy variable by averaging the five-point Likert scale of their attitudes ranging from 1 (strongly opposed), 2 (opposed), 3 (neutral), 4 (supportive), to 5 (strongly supportive), and took the positive attitude coded as one and the negative or neutral attitude coded as zero. This method is a good way

to measure managers' attitudes toward GM foods, but it still leads to a loss of variation in managers' attitudes. In this study, we averaged the Likert scale of a manager's answers to the seven questions and took it as the index of manager's attitude toward GM foods as consumers, which not only captured managers' attitudes toward different types of GM products in general, but also did not lose any variation of the food attitude variable.

Ordinary least squares (OLS) regressions were employed in the estimation:

$$Attitude_i = \pi_0 + \sum_{k=1}^{K} \pi_k x_{ki} + \xi_i \quad (5)$$

where $Attitude_i$ is managers' attitude toward GM foods; π represents the parameters to be estimated that reflect the effects of independent variables (X_s) on the food attitude; X_i are managers' personal characteristics, including age, gender, education, major of the highest degree, work time, position in the company and firm industry; and ξ_i is the error term.

3.2.3. SUR Modeling

In the model of managers' attitudes toward the adoption of GM crops as producers, one possible problem is that unobserved factors may be correlated with the managers' attitudes toward GM foods as consumers. One way to resolve this issue is to employ an instrumental variable regression. Unfortunately, given the data availability, we failed to obtain instrumental variables to identify either of these two equations. We employed a seemingly unrelated regression (SUR) model to examine the main factors that influence managers' attitudes as consumers and producers, in which the food attitude variable as consumers was excluded from Equations (3) and (4). After excluding the attitude variable from Equations (3) and (4), we conducted the Breusch–Pagan test of the independence between cross-equation error terms e_i and ξ_i. The null hypothesis of no correlation between e_i and ξ_i was rejected at the 1% significance level with corresponding test statistics of 32.0, which supports the SUR estimation.

Table 2. Attitudes toward seven types of GM foods (percent of respondents).

	Positive (Supportive)					Neutral					Negative (Opposed)				
Foods	**Food**	**Feed**	**Chemical**	**Seed**	**Total**	**Food**	**Feed**	**Chemical**	**Seed**	**Total**	**Food**	**Feed**	**Chemical**	**Seed**	**Total**
Tofu [1]	28	0	6	36	***20***	25	18	28	20	***24***	47	82	66	44	***56***
Edible oil [2]	30	6	6	36	***21***	28	47	26	24	***28***	42	43	68	40	***51***
Rice1 [3]	25	6	6	28	***18***	28	35	28	22	***27***	47	59	66	50	***55***
Rice2 [4]	25	6	9	30	***19***	30	18	26	18	***24***	45	76	65	52	***57***
Wheat [5]	28	6	8	26	***18***	23	18	23	16	***20***	49	76	69	58	***62***
Food [6]	25	12	6	28	***18***	28	24	26	18	***24***	47	64	68	54	***58***
Pork [7]	28	41	11	38	***27***	28	35	26	26	***28***	44	24	63	36	***45***
Average	27	11	7	32	***20***	27	28	26	21	***25***	46	61	67	47	***55***
GM Crop adoption	47	35	13	44	***34***	\	\	\	\	\	53	65	87	56	***66***

Tofu [1]: Tofu made using transgenic soybeans; Edible oil [2]: Soybean oil made using transgenic soybeans; Rice1 [3]: Pest-resistant transgenic rice (with relatively little to no application of insecticides and pesticides to prevent diseases); Rice1 [4]: GM rice with improved nutrition; Wheat [5]: Insect- or disease-resistant transgenic wheat; Food [6]: Food containing GM corn ingredients; andPork [7]: Pork from pigs that were fed GM feed (such as corn). Source: Managers' attitudes toward GM foods as consumers are based on the surveys in 2013–2014. Managers' attitudes toward the adoption of GM crops as producers are based on the results by Deng et al. (2017).

4. Empirical Results

4.1. Attitudes and Perception of GM Technology

The managers' attitudes toward consumption of different types of GM foods and the commercialization of GM crops are presented in Table 2. The results in the top 8 rows of the table show 55% of managers opposed the consumption of GM foods, 20% supported GM foods and 25% were neutral. Managers in the chemical and feed industries were particularly opposed. Managers had different attitudes toward different types of GM foods. Only 13% of managers in chemical firms supported the commercialization of GM crops while up to 87% were against it. In terms of attitudes toward GM foods, managers in the food and seed industries were more positive than those in the chemical and feed industries. Less than half of managers in the food and seed industries expressed concerns about GM food consumption. In terms of managers' attitudes toward different types of GM foods, 45% of managers were negative of pork from pigs that were fed GM corn, whereas over 60% of them were opposed to insect- or disease-resistant transgenic wheat. Interestingly, none of managers in the feed industry were willing to consume tofu made by transgenic soybean, but more than 40% of them were positive of pork fed by GM feed. The final row of the table shows that 66% of managers were against the cultivation of GM crops while 34% supported it. Cultivation appeared to be even less popular than consumption.

To have a better understanding of managers' attitudes toward GM food production and the reasons behind their attitudes, managers' perception of GM technology was analyzed. The questions pertaining to managers' perceptions of GM technology were surveyed: (a) Do you have safety concerns regarding GM foods? (yes, no, or not sure)? (b) What role can biotechnology related to GM production play in improving the environment? (positive, negative, or not sure)? (c) Please indicate your preference for GM products from foreign firms (using a five-point Likert scale—strongly supportive, supportive, neutral, opposed, or strongly opposed).

The results show that only a minority of respondents had positive perception of GM technology. Only 5.9% of respondents in the feed industry and 9.4% in the chemical industry believed that there were no food safety problems about GM products (Table 3). Twenty-eight percent of managers in the seed industry believed GM foods had no safety problems, but over half of managers in the chemical industry concerned about safety problems of GM products. Their perception of GM products' impact on the environment was more positive: 31% of the respondents thought it would have a positive impact compared to 26% who thought it would be negative. Most respondents opposed the application or consumption of GM products from foreign firms. Managers in the chemical industry were the most negative ones, with up to 70% against foreign GM products, whereas only 6% were supportive. Managers in the feed industry were the most supportive of foreign GM products, with over 80% of feed firms not against (either supportive or neutral) foreign GM products.

Table 3. Managers' perceptions of GM technology and GM products produced by foreign firms (percent of respondents).

Perception	Category	Food	Feed	Chemical	Seed	Total
Food safety concerns	Yes	42.5	35.3	56.6	32.0	43.1
	No	17.5	5.9	9.4	28.0	16.9
	Don't know	40.0	58.8	34.0	40.0	40.0
Impact on the environment	Positive	30.0	11.8	30.2	38.0	30.6
	Negative	32.5	17.7	24.5	24.0	25.6
	Don't know	37.5	70.5	45.3	38.0	43.8
GM products produced by foreign firms	Supportive	22.5	29.4	5.7	26.0	18.8
	Neutral	30.0	52.9	24.5	22.0	28.1
	Opposed	47.5	17.7	69.8	52.0	53.1

4.2. Potential Reasons behind Attitudes: Economic Factors

To capture economic factors influencing managers' attitudes toward the commercialization of GM crops, we surveyed firms' expectation of profit change based on firms' current product structure as well as their expectation of consumers' demand change on specific GM products. While Deng, Hu, Huang, Pray, Jin and Li [26] examined firms' expectation of profit change from the commercialization of GM rice, this study attempted to capture firms' perspective on profit change from the commercialization of all Bt and herbicide-tolerant crops, including cotton, soybean, maize and rice.

The results show that 31% of managers expected higher profits from adopting GM crops, 18% expected a loss from such adoption and 28% expected no change (Table 4). (Regarding the firms' expectation of profit change, we surveyed how firm profit would change after GM crops (cotton, soybean, corn and rice) in two traits were commercialized (1 = increase; 2 = decrease; 3 = no change; 4 = not sure). If a firm benefits (loses) from at least one GM crop and has no profit change in other crops, the firm will expect to increase profit. If a firm is not sure of profit change from any one GM crop, the firm will be not sure of profit change. If some firm benefits from at least one GM crop and loses from at least other crop, the firm profit change will be "mixed" (profit increase and decrease). If a firm has no profit change from all the GM crop, the firm will have no profit change.) Specifically, 65% of the feed firms expected increased profits while the remaining feed firms expected no change. Over 80% of the food firms and nearly 60% of the seed firms expected increased profits or profit would not have any change. Twenty-five percent of the chemical firms expected a profit loss.

Table 4. Economic factors: managers' expectations regarding their firms' profitability and consumer demand for GM products (percent of respondents).

	Food Type	Category	Food	Feed	Chemical	Seed	Total
Expectation of firms' profit change	/	Gain	37.5	64.7	7.5	38.0	30.6
	/	Loss	15.0	0	24.5	18.0	17.5
	/	No change	45.0	35.3	20.8	20.0	28.1
	/	Not sure	2.5	0	34.0	22.0	18.8
	/	Mixed	0	0	13.2	2.0	5.0
Expectation of consumer demand for GM products	Soybean oil made using GM ingredients	Decrease	35.0	35.3	43.4	48.0	41.9
		No decrease	47.5	41.2	24.5	36.0	35.6
		Not sure	17.5	23.5	32.1	16.0	22.5
	GM rice	Decrease	37.5	47.1	34.0	34.0	36.3
		No decrease	42.5	29.4	26.4	54.0	39.4
		Not sure	20.0	23.5	39.6	12.0	24.3
	Pork from pigs fed GM maize and GM soybeans	Decrease	37.5	41.2	39.6	52.0	43.1
		No decrease	47.5	41.2	24.5	30.0	33.8
		Not sure	15.0	17.6	35.9	18.0	23.1

Another important factor influencing managers' expectations of firm profit change was their opinions of consumer demand change due to GM products. In contrast to managers profit expectations, 36–43% of managers thought the impact of GM foods on demand would be negative. One-third of managers expected that consumers would not reduce their purchase of GM products. Nearly 50% of managers in the seed industry, for example, expected that consumers would reduce the purchase of soybean oil and pork if they found out these products were made with GM ingredients. Only 30% of managers expected no reduction. In addition, expectation of consumer demand varied by different types of foods. For example, managers in the seed industry expected that consumers would reduce their demand for GM soybean oil and pork, but not for GM rice.

4.3. Determinants of Manager Attitudes toward Consumption and Cultivation of GM Food

To analyze the relative importance of the different factors on manager's attitudes toward GM food consumption and cultivation, the analysis must move beyond bivariate relationships. Therefore,

we estimated Equations (4) and (5). The estimation results of the logit, OLS and SUR models are provided in Table 5, which presents the marginal effects of the independent variables on managers' attitudes toward GM food crop cultivation and consumption. The results of the SUR and the separate estimations are qualitatively similar.

Table 5. Marginal effects of factors that influence respondents' attitudes toward GM food as consumers and the commercialization of GM crops as producers.

Category	Variable	Separate Regressions		SUR Estimation	
		Food Attitude	Adoption Attitude	Food Attitude	Adoption Attitude
Personal acceptance of GM foods	Food attitude		0.189 ***		
			(0.026)		
Manager-level characteristics	Biology or related major	−0.005	−0.021	−0.005	−0.004
		(0.266)	(0.076)	(0.266)	(0.092)
	Age (years)	−0.003	−0.012 *	−0.003	−0.010
		(0.025)	(0.007)	(0.025)	(0.009)
	Male	−0.038	−0.127	−0.038	−0.104
		(0.285)	(0.079)	(0.285)	(0.095)
	Work time (years)	0.011	0.006	0.011	0.007
		(0.022)	(0.006)	(0.022)	(0.007)
	Bachelor's or above	0.374	−0.025	0.374	0.032
		(0.244)	(0.069)	(0.244)	(0.084)
	CEO	−0.126	−0.029	−0.126	−0.010
		(0.210)	(0.056)	(0.210)	(0.070)
Firm-level characteristics	State-owned	/	0.066	/	−0.016
			(0.079)		(0.080)
	Registration capital	/	−0.010	/	−0.106
			(0.129)		(0.166)
	No. of employees	/	−0.076	/	−0.084
			(0.118)		(0.095)
	Food firm	0.599 **	0.285 ***	0.599 **	0.255 **
		(0.254)	(0.097)	(0.254)	(0.102)
	Feed firm	0.294	0.219 **	0.294	0.102
		(0.360)	(0.113)	(0.360)	(0.139)
	Seed firm	0.577 **	0.144	0.577 **	0.198 *
		(0.286)	(0.093)	(0.286)	(0.108)
Economic factors	Gain	/	0.025	/	0.082
			(0.060)		(0.078)
	Loss	/	−0.262 ***	/	−0.154 *
			(0.103)		(0.087)
	Mixed	/	−0.101	/	−0.192
			(0.137)		(0.144)
	Not sure	/	0.020	/	−0.033
			(0.079)		(0.089)
	No decrease in oil purchases	/	0.106 *	/	0.194 **
			(0.064)		(0.081)
	No idea regarding changes in oil purchases	/	0.025	/	−0.025
			(0.092)		(0.097)
	No decrease in rice purchases	/	−0.095	/	−0.036
			(0.069)		(0.075)
	No idea regarding changes in rice purchases	/	−0.207 ***	/	−0.138
			(0.075)		(0.089)
	No decrease in pork purchases	/	0.078	/	0.065
			(0.068)		(0.075)
	No idea regarding changes in pork purchases	/	0.178	/	0.111
			(0.083)		(0.090)
	Biotechnology products	/	0.102 **	/	0.098
			(0.053)		(0.062)
	Biotechnology R&D	/	0.199 ***	/	0.155 **
			(0.069)		(0.075)
	Constant	1.878 ***			0.431
		(0.769)			(0.277)

***, **, and * represent the 1%, 5%, and 10% statistical significance levels, respectively.

Figures in parentheses are standard errors and those in brackets indicate the standard errors of the marginal effects

In the model of managers' attitudes toward the adoption of GM crops, sociodemographic characteristics—gender, work experience, education background (indicating bachelor or above), biotechnology knowledge (indicating biology or related major) and position (indicating firm CEO)—were insignificant. The only sociodemographic characteristics found to be statistically significant in whether a manager would support the adoption of GM crops was manager's age. The estimated coefficient is negative, suggesting that older managers were more likely to be against the GM food crop cultivation in China.

Regarding firm characteristics, the firm's industry had a significant effect on the managers' attitudes toward GM crop adoption while both ownership and firm size did not. The estimated coefficients with respect to the firm's industry were positive, implying that managers who were in the food, feed, and seed industries were more likely to push for the cultivation of GM crops than the ones in the chemical industry.

The variables measuring economic factors, as we expected, were significantly associated with their attitudes toward the adoption of GM crops. Those who expected profit losses from adopting GM crops were less likely to support the GM crop adoption than the ones who expected no change in their profit. However, firms that expect to gain, or have mixed expected results (benefiting from some GM crops while losing money from another GM crops), or were not sure of profit change had no significant effect on the dependent variable. The results imply that the firms that expected losses from the GM crop adoption might be a major group of firms opposed to GM crop adoption in China. Chemical firms in India, for instance, are very opposed to the introduction of new GM crops because of a big drop in chemical sales [8]. The variables measuring managers' expectation of demand change of consumers, firms engaging in biotechnology R&D and selling biotechnology products were also shown to have a positive and significant effects on whether a manager would be willing to support the cultivation of GM crops.

With respect to expectation of consumer demand, those who expect consumer demand would not reduce regarding GM soybean oil were more likely to support the adoption of GM crops. Those who have no idea of consumer demand change were less likely to support the adoption. The results imply that consumers' positive attitudes toward GM products could encourage managers to support the GM crop adoption. In addition, investing in biotechnology R&D and having experience of selling GM products increased the likelihood of firms to support the adoption of GM crops.

Managers' personal acceptance of GM foods as consumers significantly affected the probability that they supported the cultivation of GM food crops. The positive coefficient suggests that managers who felt more positive about GM food consumption were more likely to support the government policy of adopting GM crops in China.

In the model of managers' attitudes toward GM foods as consumers, unlike our expectations, managers' sociodemographic characteristics did not significantly influence their attitudes toward GM foods as consumers. This result is different from Deng, Hu, Huang, Pray, Jin and Li [26], who found that managers' biotechnology knowledge and age were positively associated with managers' attitudes toward GM foods. It might be due to different methods to deal with food attitude variables. However, firm industry, consistent with Deng, Hu, Huang, Pray, Jin and Li [26], was a significant predictor of managers' attitudes toward GM foods. The managers in the food and seed industries had more positive attitudes toward GM foods than their counterparts in the chemical industry.

4.4. Bivariate Relationship between Perceptions and Attitudes

Given the possibility of endogeneity, we conducted additional analysis to capture the relationships between managers' perceptions and attitudes. The results show that managers' attitude toward the commercialization of GM crops was highly associated with their perception of GM food consumption. Perceived adverse effect of GM product-related technology drives managers' opposition to the adoption

of GM crops (Table 6). Eighty-three percent (n = 34) of 41 managers who believed that GM technology exerted a negative impact on the environment did not support the adoption of GM crops. Eighty-three percent of managers who were concerned about GM food safety opposed adoption of GM crops. Contrarily, perceived benefits of GM product-related technology were associated with positive attitudes. Seventy-seven percent (n = 30) of 49 managers who perceived a positive effect of GM technology on the environment embraced the GM crop adoption, while 78% (n = 21) of 27 managers who had no safety concern of GM food are supportive of GM crop cultivation. In addition, 73% of managers who supported GM products from foreign firms supported the adoption of GM crops in China.

Table 6. Relationship between perception and adoption attitudes (No. of firms).

Perception	Category	Adoption Attitude as Producers		
		Supportive	Opposed	Total
Impact on the environment	Positive	30	19	49
	Negative	7	34	41
	Do not know	17	53	70
Food safety problem	Yes	12	57	69
	No	21	6	27
	Do not know	21	43	64
GM products from foreign firms	Supportive	22	8	30
	Opposed	15	30	45
	Neutral	17	68	85

5. Discussion and Conclusions

This study was one of the first to report on the perceptions and attitudes of Chinese agribusiness managers in the food, feed, chemical and seed industries toward the cultivation of GM food crops. Similar exercises were conducted focusing on the Chinese food industries' perception of GM foods [62,63]. However, these studies have interviewed a very limited number of companies in the food industry but none in other industries or focused on the firms' other activities [26].

The results show that most agribusiness firm managers in the food, feed, chemical and seed industries in China are against the cultivation of GM crops, similar to the food manufacturers in Australia who are reluctant to use GM products in their production [64]. However, they are different from Kenyan food firms who would like to make the decision on using GM foods in their companies on a case-by-case basis [55]. In terms of attitudes toward GM foods as consumers, over half of managers are reluctant to consume GM foods and only 20% are willing to, which is similar to the results of scientists (29%) and urban consumers (25%) in China [6,65].

Chinese agribusiness managers as consumers are generally concerned about GM technology. Nearly half of managers think that GM foods have food safety issues and oppose the use of GM products made by foreign firms. This is consistent with the results of previous studies regarding Chinese gatekeepers' perception of GM technology, in which informants of food-importing and distribution companies express a high degree of uncertainties about GM food "unnaturalness" [63]. This may be partially ascribed to numerous negative media reports on GM technology and the food safety issues in China [5]. Although the government has made great efforts to present evidence that GM foods are safe for consumption, this study suggests that the information about positive or beneficiary attributes of GM product and its safety have had a limited effect on their views on safety of and/or support for GM food cultivation.

Nearly one-third of all firms expect to gain profits from new GM crop cultivation while only 17% expect to lose money. Sixty-five percent of feed companies expect to profit. Seed firms may increase their profits through the increase in their sales, while feed and livestock firms could earn money resulting from the decline of grain costs [37]. However, managers are not optimistic about the consumer demand for GM products. More than 40% of managers think that Chinese consumers

would reduce their purchase of food with GM ingredients. Their worry fits with the results of the study about Chinese consumers, which concluded that most Chinese consumers are concerned about GM food safety [5,66]. However, the policies and attitudes of government may exert a great impact on the consumers' attitudes in the future [63].

Importantly, the results show that managers' attitudes toward the adoption of GM crops as producers are significantly affected by their personal acceptance of GM foods as consumers, as well as economic factors influencing firm profitability (including managers' expectation of profit change and consumer demand for GM products, biotechnology R&D and selling GM products). The results that economic factors influence managers' attitudes are consistent with studies in Europe and India where chemical firms suffered profit losses from GM crop adoption and strongly opposed adoption [8,9]. The results that agribusiness firms are highly responsive to consumer purchasing behavior are consistent with studies in Europe and some developing countries where consumer reluctance to embrace GM technology drove the food manufacturers to refuse GM technology [42,43,64]. The results that managers' attitudes toward GM foods as consumers significantly influence their attitudes toward the adoption of GM crops as producers imply that managers' personal opinions of GM foods could have significant impact on managers' decision on whether firms support the GM technology.

These findings reveal three lessons that policy makers and interest groups can learn from to facilitate support for the commercialization of GM crops in China. First, expected losses clearly reduce agribusiness managers approval of GM crop cultivation in China. The pesticide industry expects the most losses from the cultivation of GM crops and is opposed to it. Government supporters of GM cultivation need to find ways to support the losers. This could be in the form of state-owned enterprises buying out some of the losing firms or approving herbicide tolerant crops such as glyphosate tolerant cotton, which would help improve herbicide producers' profits.

Second, managers' concerns about the safety of GM food crops also influences their support for GM crop cultivation even if it goes against their economic interests. This highlights the importance government programs to strengthen the Chinese Food and Drug Administration that regulates food safety and increase public awareness of their activities and successes in improving food safety in general. It also requires the government to successfully control the unauthorized spread of GM crops such as Bt maize in northern China. A campaign to educate managers and consumers to improve their perception of GM technology through providing them objective knowledge and information might help.

Third, the strength of the concerns about food safety combined with concerns about lost profits suggests that strong support for GM food crop cultivation is not likely to come from agribusiness. However, there is considerable diversity of opinions of managers within each of these industries. Forty percent of managers did not know whether they needed to be concerned about food safety or not. Thirty one percent thought GM crops could have a positive impact on the environment, 44 percent did not know while 26 percent believed it would have a negative impact. These figures suggest managers attitudes are not entirely negative despite the barrage of negative publicity.

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