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Consumers' perceptions on GM food safety in urban China

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Abstract

The debate about the safety of genetically modified (GM) food has attracted public attention in concurrence with the rapid development of agricultural biotechnology. This paper examines the consumers' perceptions on the safety of GM food in China. Based on a unique survey dataset, this study shows that consumers in urban China have significantly changed their perceptions on GM food safety. The percentage of consumers who perceived such food as unsafe for consumption increased by more than 30% in the 2002–2012 period. Approximately half of the consumers did not have an opinion on this issue. Major shifts have been occurred after 2010, likely because of the increasing influence of negative media reports on GM technology in recent years. Several individual and household's characteristics are shown to significantly affect consumers' perceptions on GM food safety, such as gender, education, food allergy experience and resident city size. The paper concludes with policy implications.

Keywords: food safety, GM food, urban China, consumers, perception

1. Introduction

Despite the rapid area expansion of biotech crops, also known as genetically modified (GM) or transgenic crops, globally, the debate on GM technology has persisted. After the United States first approved commercial production of GM tomatoes in 1994, there has been an increase in the number of countries adopting GM crops and a rapid expansion of GM crop areas. By 2013, 27 countries had planted more than 175 million ha of biotech crops combined, providing significant economic, health, environmental, and social benefits to millions of farmers (James 2013). Major biotech crops include GM soybean, maize, cotton and canola. However, debates on GM food have been accompanied with rapid GM crop area expansion. The debate areas range from the ecological or environmental impacts of agricultural biotechnology (Qaim and De Janvry 2005; Wang *et al.* 2009; Brookes and Barfoot 2013) to GM food safety (Gaskell *et al.* 1999; Kuiper *et al.* 2001; Domingo and Gié Bordonaba 2011).

Among various debates, the safety of foods produced using GM technology has increasingly attracted attention. The hot debate on GM food safety started in developed countries in the early 1990s and has been rapidly spread by the media worldwide (Kessler *et al.* 1992; Uzogara 2000; Dona and Arvanitoyannis 2009). Key (2008) points out that except for a few flawed studies or reports that claim potential health impacts from GM products, such as Ewen and Pusztai (1999), a large number of studies have shown that

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the commercialized GM products are equally safe as their conventional counterparts (Domingo and Gié Bordonaba 2011). The World Health Organization (WHO) has declared that all GM products on the international market have passed risk assessments by national authorities (Domingo 2007). However, Chinese consumers do not have enough knowledge about GM technology (Huang *et al.* 2006). The information reported in media is often unreliable and misreports the science. Therefore, despite the strict risk assessments conducted on commercialized GM crops by national biosafety regulatory authorities and despite showing a substantial equivalence to the non-GM crops, the safety of foods containing GM products has continued to be a major public concern.

China zealously embraced GM technology in the 1980s and 1990s, however, the country has recently experienced a hot debate on the safety of GM food. China has invested significantly in agricultural biotechnology and has considered it a major tool to boost agriucltural productivity (Huang *et al.* 2002). Previous studies on consumer acceptance of GM foods also show that Chinese consumers had a positive attitude toward GM food compared to other consumers worldwide (Li *et al.* 2003; Zhong *et al.* 2003; Huang *et al.* 2006; De Steur *et al.* 2010; Zhang *et al.* 2010; Qiu *et al.* 2012). However, these consumer attitude studies were based on survey data before the debate on GM food safety started increasing. Particularly, after China provided safety certificates for GM rice in 2009, an anti-GM movement has appeared widely in various domestic media. There is concern on whether this anti-GM movement has affected consumer's perception of and attitude towards GM food. Understanding how consumers perceive the safety of GM food for human consumption is critical for future agricultural biotechnology development.

This study examines consumer perceptions on the safety of GM food in urban China[1]. Specifically, we investigate the following two questions: 1) How do consumers perceive the safety of GM food for human consumption in urban China? 2) What are major factors affecting such consumer perceptions? To answer these questions, this study uses a unique dataset from surveys on consumer perceptions and attitudes regarding GM food in urban China in 2002, 2003, 2010, and 2012.

The remainder of this paper is organized as follows. Section 2 presents the data and sampling methods. Survey results based on our descriptive analysis are discussed in Section 3. Section 4 develops an econometrical model of consumer perceptions on the safety of GM food and presents our estimation results. The last section summarizes and concludes.

2. Sampling methods and data

2.1. Sampling methods

To examine the current trends of consumer perceptions on the safety of GM food in urban China, this study uses data from four surveys conducted by the Center for Chinese Agricultural Policy, Chinese Academy of Sciences in 2002, 2003, 2010, and 2012. In each survey, we selected a number of cities from the Urban Household Income and Expenditure's Survey (UHIE) conducted by the National Bureau of Statistics of China (NBSC). UHIE provides national representative data samples for urban China and is China's official source of information on urban income and expenditure; furthermore, it has been widely used for consumption and income studies in China. Fig. 1 shows the locations of surveyed provinces, which are highlighted in darker colors.

The first two rounds of surveys were conducted in 11 cities in North China (Beijing and Shandong) and East China (Shanghai, Zhejiang, and Jiangsu) in 2002 and 2003. These cities include two big (Beijing and Shanghai), three medium size (Nanjing of Jiangsu Province, Jinan of Shandong Province, and Ningbo of Zhejiang Province), and six small cities (Dezhou and Weihai in Shandong Province, Yancheng and Nantong in Jiangsu Province, and Shaoxing and Jinhua in Zhejiang Province)[2]. In 2002, we randomly selected 1 005 individuals from the 2 300 samples provided by UHIES for these 11 cities. We used the same cities in 2003 to repeat the survey. Because the NBSC normally replaces one-third of its UHIE samples each year, we were able to interview only 666 individuals who were interviewed in 2002 and 334 new households randomly selected from the new UHIES samples in the same cities in 2003. Because data from 2003 include both new samples (334 individuals, named as "2003a" thereafter) and repeated or old samples (666 individuals, named as "2003b" thereafter), we analyze these data separately in the rest of this paper. Detailed sampling and a survey of these data can be found in studies by Huang *et al.* (2006) and Qiu *et al.* (2012).

The third survey was conducted in Jiangsu and Guang-

[1] China's urban population accounted for 52.6% of the nation's total in 2012 (NBSC 2013).

[2] In this paper, cities with population exceeding 8 million are defined as big cities, between 2 and 8 million are medium cities, and those under 2 million are small cities.

Fig. 1 The locations of surveyed provinces in China.

dong provinces in 2010. In Jiangsu, our 2010 survey was implemented in the same three cities (Nanjing, Yancheng, and Nantong) surveyed in 2002–2003, but the households and individuals interviewed in 2010 differed from those surveyed in 2002–2003. In 2010, Guangdong was added to represent consumers from South China. The survey in Guangdong was also conducted in the three cities Guangzhou (big), Zhongshan (small), and Meizhou (small) cities. A total of 430 individuals were randomly selected from the UHIES samples for these six cities. Excepting one individual that did not complete the survey, we obtained 429 valid samples used in this study.

The last survey was conducted in five cities in five provinces across China in 2012: Harbin in Heilongjiang (middle size city, Northeast China), Taiyuan in Shanxi (middle size city, North China), Taizhou in Zhejiang (small size city, East China), Nanning in Guangxi (middle size city, South China), and Lanzhou in Gansu (middle size city, Northwest China). The 2012 survey covered 1 002 individuals who were randomly selected from the UHIES samples for these five cities.

2.2. Data collection

We conducted in-person and in-house interviews and obtained surveys for a total of 2 770 individuals (1 005 in 2002; 334 in 2003; 429 in 2010; and 1 002 in 2012) with 3 436 observations (666 were repeated in 2003) from 19 cities across China (row 1, Table 1). In the surveys for each year, to avoid potential selection bias for individuals interviewed in each household, the enumerators were asked to interview the adult (ages 16 to 70) they met first when they arrived at the interviewee's apartment. Interviews were conducted by the authors, trained graduate students, and professional

Table 1 Household and individual characteristics, 2002–2012

	2002 (*n*=1 005)	2003a (*n*=334)[1)]	2010 (*n*=429)	2012 (*n*=1 002)
Respondent's characteristics				
Share of male (%)	41	49	41	34
Age (years)	47	48	47	49
Education (%)				
≤Junior high school	36	32	28	31
Senior high school	38	38	32	50
≥College	26	30	40	19
Occupation (%)				
Government	22	20	21	26
Enterprises	44	32	35	27
Retired	24	32	28	36
Others[2)]	10	16	16	11
Household characteristics				
Monthly per capita income (CNY)[3)]	844	1115	1 439	1 535
Family experienced food allergy (%)	9	9	19	7
Resident in (%)				
Small city	30	29	53	19
Medium city	30	25	23	81
Big city	40	46	24	0

[1)] The sample under 2003a is the new sample surveyed in 2003.
[2)] Others include student, home work, soldier, non-profit organization, domestic service, and searching or no job.
[3)] Consumer price index was used to deflate the nominal income (base year is 2002).
The same as below.

enumerators from each provincial branch of NBSC[3].

To avoid the effects of multiple survey rounds, we established the following rules for the surveys. We used the same survey instruments, asked the same set of questionnaires, and provided the same training course to our interviewers in each round of surveys. While the survey covered a wide range of information, this study used only a subset of data related to the research questions mentioned earlier, that is, individual and household characteristics (summarized in Table 1) as well as people's perceptions on GM food safety. As for perceptions on GM food safety, we asked each respondent to select one of the following three choices: 1) safe for consumption; 2) unsafe for consumption; 3) no idea.

2.3. Characteristics of individuals

The characteristics of respondents show that the sample represents a wide range of consumers. In general, we interview more women than men in each year. This was expected, because women stay at home more often than men do. The respondents' age ranged from 16 to 70 with an average age of 47 in 2002 and 49 in 2012 (Table 1). A wide range of education levels was also covered, from less than junior high school to college and above. Respondent's employment included those working in government organizations and enterprises or companies as well as retired people and others (Table 1).

With the rapid growth of China's economy, monthly per-capita income in real terms increased by 82% from 2002 to 2012 (Table 1)[4]. The surveys cover different-sized cities in each year except for the 2012 survey. The proportion of families that experienced food allergies ranged from 7 to 19%. These variations may help us examine whether there is a relationship between consumers' food allergy experiences and their perceptions on GM food safety.

3. Consumers' perceptions on GM food safety

3.1. Consumers' perceptions

The ratios of consumer perceptions on GM food safety are presented in Table 2. We divided all respondents into three groups based on their perceptions regarding GM food for consumption: "unsafe", "safe", and "no idea". Table 2 shows

[3] Because the surveys were conducted in different provinces in 2010 and 2012, two major efforts were made to ensure that samples from different provinces are comparable: 1) We selected all households from NSBC's urban income and expenditure survey samples; and 2) we used the same stratified sampling method to randomly select our samples from the NSBC samples.

[4] All monetary values were normalized using the consumer price index with 2002 as the base year. The increase in income (82%) in our sample was lower than that (180%) for China's average urban residents in 2002–2012. This is because our survey shifted from relatively rich provinces (e.g., Beijing, Shanghai, Jiangsu, Zhejiang, and Shandong) in 2002 to some less-developed ones (e.g., Shanxi, Gansu and Guangxi) in 2012.

the following three interesting results.

First, for all samples in 2002–2012, nearly half of respondents (47%) did not have a clear stance on GM food safety, and the remainder of respondents were almost equally distributed between two groups of consumers who perceived GM food as being either unsafe or safe (Table 2). For example, 27% of consumers considered GM food safe for human consumption, which was only slightly higher than the percentage of consumers who considered GM food unsafe for consumption (26%). The relatively high amount of consumers with no stance on GM food safety compared to those with either positive or negative perceptions may reflect the general public's lack of knowledge on the GM technology in urban China (Huang *et al.* 2006).

Second, there have been significant changes in consumer perceptions on GM food safety over time[5]. Only 13 to 16% of respondents considered GM food unsafe for human consumption in 2002–2003, and this number increased to 45% in 2012 (Table 2). On the other hand, the percentage of respondents who perceived GM food as safe for consumption decreased from more than 35% in 2002–2003 to only 13% in 2012.

Third, most significant changes in consumers' perceptions have occurred only in recent years (2010–2012). The proportion of respondents considering GM food to be safe for human consumption declined by 16% from 29% in 2010 to 13% in 2012 (Table 2). On the other hand, the number of consumers considering GM food unsafe for human consumption has rapidly increased. Compared with the number in 2002, the proportion of these consumers increased by 5% (form 13 to 18%) by 2010 and by 32% (13 to 45%) by 2012.

3.2. Descriptive analysis of factors affecting consumer perceptions

The reasons for significant changes of consumer perceptions on GM food safety in 2010–2012 compared to 2002–2003 cannot be easily identified within a descriptive analysis framework. However, we explore some possible explanations in the next section while presenting and discussing the results of the econometric analysis. In the rest of this section, we focus our discussions on the relationships between these consumer perceptions and their characteristics. The descriptive results for the two sub-periods, 2002–2003 and 2010–2012, are summarized in Table 3. The results show that consumer perspectives on GM food safety are likely associated with some individual and household characteristics. The following discussions focus on respondents who consider GM food unsafe for human consumption (Table 3).

Table 2 Percentage of consumers' perceptions on genetically modified (GM) food safety for human consumption in urban China by year (2002–2012, %)[1)]

Year	Unsafe	Safe	No idea
2002	13	37	50
2003a	16	35	49
2003b	13	38	49
2010	18	29	53
2012	45	13	42
Average	26	27	47

[1)] Source: authors' survey.

The results show some differences in the respondents' perceptions on GM food safety between males and females but no clear relationships were observed among age groups. There were a larger proportion of female respondents, compared to their male counterparts, who did not trust GM food safety (Table 3). Differences among various respondent age groups in such perceptions (safe or unsafe) were moderate.

Education level appears to be negatively associated with consumer perceptions on GM food safety. Respondents with higher education were more likely to believe that GM food was unsafe for consumption (Table 3). Higher levels of education may imply that consumers are more likely to access a wider range of information about novel technologies, such as transgene technology. As the public encounters a higher number of negative reports on GM food, better-educated consumers may have a more negative outlook about it.

On the perceptions by occupation, respondents who worked in government organizations had a more negative perception on GM food safety than the other three groups did (Table 3).

The proportion of respondents perceiving GM food as unsafe is positively associated with their household income. For example, in 2002–2003, 12% of respondents in households with an average monthly per-capita income of less than 650 CNY perceived GM food as unsafe compared to 20% of respondents in households with an average monthly per-capita income of more than 1 500 CNY (Table 3). In general, respondents with family members with food allergies were more likely to consider GM food as unsafe for human consumption (Table 3), possibly because of their increased concerns about food safety.

The descriptive analysis does not reveal an apparent

[5] We checked data from the two provinces where the surveys were conducted in both 2002–2003 and 2010 (Jiangsu) and in both 2010 and 2012 (Zhejiang). The results showed that the proportion of consumers that perceived GM food as unsafe for consumption increased moderately by 2010 and significantly by 2012, similar to the trend for the entire sample.

correlation between city size and consumers perceptions on GM food safety, although beliefs differed largely among residents of different cities. Because the income and survey timing (2002–2012) are somewhat correlated with city size[6], the next section applies an econometric model to quantitatively explore this relationship and other issues discussed above.

4. Model and estimation results

4.1. Econometric model and estimation

Based on the descriptive analysis of various factors that simultaneously affect consumers' perceptions on GM food safety, we developed the following econometric model in this section.

$$F_{it}=f(D_{it}, P_{it}, H_{it}, C_{is})+\xi_{it} \quad (1)$$

Where, the dependent variable F_{it} is the ith consumer's perception of GM food safety in year t and is defined using the following three alternatives: unsafe/safe (a comparison of the perception that GM food is unsafe or safe for consumption, unsafe/no idea (a comparison between "do not know" and the perception that GM food is unsafe for consumption), and safe/no idea (a comparison between "do not know" and the perception that GM food is safe for consumption). Given the nature of dependent variable F_{it}, eq. (1) is estimated using a multinomial logit (MNL) regression model. Eq. (1) can be estimated using the MNL if the assumption

Table 3 Percentage of consumers' perceptions on GM food safety for human consumption in urban China by respondent and household characteristics (2002–2012, %)

	2002–2003			2010–2012		
	Unsafe	Safe	No idea	Unsafe	Safe	No idea
Respondents' individual characteristics						
Gender						
Male	13	40	48	35	21	44
Female	14	34	52	38	16	46
Age						
≤39 years	16	38	46	39	18	44
40–45 years	13	34	52	41	17	42
46–55 years	14	32	54	39	15	45
>55 years	9	42	48	32	20	48
Education level						
≤Junior high school	10	33	57	31	20	49
Senior high school	14	39	47	40	15	45
≥College	18	38	44	40	18	41
Occupation						
Government agencies	15	39	46	45	16	40
Enterprises	15	33	53	38	18	44
Retired	11	39	51	33	18	49
Others	13	40	47	32	19	49
Household characteristics						
Monthly per capita income (CNY)						
≤650	12	35	53	34	19	47
650–1 000	12	39	49	35	19	46
1 000–1 500	16	39	45	35	16	49
>1 500	20	26	54	41	18	41
Has food allergy family member						
Yes	16	33	51	38	13	49
No	13	37	50	37	18	45
Resident in						
Small city	10	36	54	31	24	45
Medium city	13	43	44	41	14	44
Big city	17	32	51	26	19	54

[6] In China, city size is generally positively correlated with income. For example, the monthly average income per capita in 2002 in real terms was 659, 821, and 1 003 CNY for small, medium, and large cities, respectively. Similar patterns were also observed in 2010 and 2012.

of independence of irrelevant alternatives (IIA) is held. To do this, we conduct a Hausman test. The results show that that we can not reject the null hypothesis of IIA assumption, which means the MNL specification is appropriate for our data[7]. The sign of the estimated parameter represents the nature of the impact, and its magnitude reflects the relative risk ratio between the two alternative choices (Zhang and Kai 1998).

There are four groups of independent variables in eq. (1): year dummies (D_{it}), respondent's personal characteristics (P_{it}), respondent's household characteristics (H_{it}), and the residential city size (C_{is}). Specifically, D_{it} is a vector for years the survey was conducted and includes four time dummies, Y_{03a}, Y_{03b}, Y_{10}, and Y_{12}. We separated the sample in 2003 into two subsamples, Y_{03a} and Y_{03b}, as discussed in the data section, to see whether they differed from each other. The variable Y_{03b} investigates whether taking our survey in 2002 affected respondents' opinions on GM food safety in 2003. Y_{10} and Y_{12} indicate 2010 and 2012 samples, respectively. P_{it} includes the following variables: respondent's age, gender, education and occupation. Excluding age, which is a continuous variable, all others are measured as dummy variables. For the gender dummy, males were assigned a value of 1 and females a value of 0. For education, there are two dummy variables, one for completion of senior high school and the other for completion of college/higher-level education. These were compared to those who had a junior high school and lower education levels. Occupation comprises the following three dummy variables: working in government organizations, retired persons, and others (see Table 1 for details). The group for comparison includes individuals working in enterprises or companies. H_{it} is a vector including monthly household per-capita income (CNY) and one dummy variable on whether family members experienced food allergies. C_{is} includes two dummy variables, one for medium city (taking a value of 1 if it is a medium city and 0 otherwise) and the other for big city (taking a value of 1 if it is a big city and 0 otherwise).

To examine whether the estimation parameters differ between the two sub-periods, we use three alternative samples in the estimation: the whole sample (Table 4), the 2002–2003 subsample (Appendix A), and the 2010–2012 subsample (Appendix B).

4.2. Estimation results

Overall, the estimation results are reasonable. About half the estimated coefficients are statistically significant. Most coefficients have the expected signs and are largely consistent with the descriptive analysis presented in the previous section.

After controlling for individual and household characteristics, the estimation results suggest that a significant shift occurred in respondents' GM food safety perceptions. For example, based on the entire sample, the estimated coefficients for the 2010 and 2012 dummy variables in the unsafe/safe equation are statistically significant at the 1% level and larger than 1 (1.873 in 2010 and 13.80 in 2012; column 1, Table 4). These numbers imply that compared with the respondents in 2002 and after controlling for the effects of other factors, the relative risk for consumers perceiving GM food as unsafe relative to safe increased by a factor of nearly 2 by 2010 and by approximately 14 by 2012. Significant changes are also found between 2002 and 2012 in the unsafe/no idea and safe/no idea categories (columns 2 and 3, Table 4, respectively). Based on the 2002–2003 subsample (Appendix A), changes in consumer perceptions were not statistically significant between 2002 and 2003 (rows 1 and 2, Appendix A). However, a significant difference is seen between 2010 and 2012 for the subsample 2010–2012 (row 1, Appendix B). These results are largely consistent with estimates based on the total sample (Table 4).

While we are not able to explicitly identify the exact forces that have driven the changes in such consumer perceptions between 2002–2003 and 2010–2012, we suggest the following possibilities. First, the decision of China to promote GM technology R&D in 2008 might have induced an increase in GM opposition activities in China thereafter. In 2008, in addition to the existing research programs on GM biotechnology, the State Council approved a new and major 12-year "GM Special Program" to support R&D on GM crops and animals with a total budget 26 billion CNY (or USD 3.8 billion). Second, China issued production safety certificates for Bt rice and phytase maize in August 2009. As Bt rice and phytase maize were still awaiting regional varietal demonstrations and registration, it was expected at the time that they would be cultivated for large-scale production within 3–4 years[8]. However, a couple of

[7] Two Hausman tests are conducted. In one, the multinomial logit (MNL) results are compared with those from a logit between "unsafe" and "safe" samples. In the other one, the MNL results are compared with those from a logit between "no idea" and "safe" samples. The *P*-values of the resulting test statistics are 0.998 and 1.000, respectively. These results provide evidences that we fail to reject the assumption of irrelevant alternatives (IIA), which implies that the MNL model is appropriate specification.

[8] However, these Bt rice and phytaes maize have never been commercialized and their production safety certificates have been expired after August, 2014.

Table 4 Estimation results of consumers' perceptions on GM food safety for consumption, whole sample, multinomial logit model[1)]

	Consumers' perceptions on GM food safety		
	Unsafe/Safe	Unsafe/No idea	Safe/No idea
D_{it} (survey time)			
2003a	1.386* (0.272)	1.267 (0.237)	0.914 (0.129)
2003b	0.970 (0.160)	1.051 (0.167)	1.083 (0.119)
2010	1.873*** (0.353)	1.310 (0.232)	0.700** (0.0992)
2012	13.80*** (2.456)	4.970*** (0.783)	0.360*** (0.0512)
Respondent's characteristics			
Age	0.997 (0.00620)	0.987** (0.00538)	0.991* (0.00500)
Gender	0.736*** (0.0808)	0.993 (0.0979)	1.349*** (0.116)
Education level			
Senior high school	1.139 (0.147)	1.377*** (0.157)	1.209* (0.120)
≥College	1.476*** (0.223)	1.843*** (0.252)	1.249* (0.148)
Worked in			
Government agencies	0.878 (0.122)	1.073 (0.132)	1.221* (0.140)
Retired	0.701** (0.125)	1.018 (0.159)	1.453*** (0.207)
Others	0.684** (0.121)	0.912 (0.147)	1.334** (0.182)
Household's characteristics			
Monthly per capita income	1.017 (0.0665)	1.033 (0.0709)	1.015 (0.0666)
Family experienced food allergy	1.407** (0.232)	1.274 (0.190)	0.905 (0.122)
Medium city	1.023 (0.142)	1.204 (0.148)	1.176 (0.123)
Big city	1.734*** (0.259)	1.533*** (0.214)	0.885 (0.0973)
Constant	0.330*** (0.0985)	0.247*** (0.0660)	0.748 (0.177)
R^2	0.058	0.058	0.058
Hausman test (χ^2)	4.60	–2.46	–0.23
Samples	3436	3436	3436

[1)] Hausman test was used for test the assumption of "independence of irrelevant alternatives" (IIA). The null hypothesis is that difference in coefficients is not systematic. Data in parentheses indicate robust standard error.
*, significant at 10%, **, significant at 5%, and ***, significant at 1%.

months after safety certificates for GM rice and maize were issued (particularly after those for Bt rice were issued), GM opponents launched a series of anti-GM initiatives in the public media, especially the internet (i.e., since early 2010). Last but not least, many food safety scandals have struck recently, China's biggest food crisis occurred in late 2008 when milk suppliers were discovered to add melamine to artificially boost the protein readings of their milk, resulting in thousands of child illness cases and an alarming death toll (Jia *et al.* 2012). With this background, it is not surprising that the number of consumers with negative views on GM foods has risen significantly since 2010.

To further understand the significant changes in recent years, we examine the relationship between consumer awareness of GM food and their perceptions of GM food safety in 2002, 2010, and 2012 (Appendix C). As we expected, the share of respondents who had heard of GM food increased over time (column 1, Appendix C). We found that the awareness of GM food was positively associated with safe perceptions regarding GM food in 2002, but an opposite relationship had been observed in recent years, particular for 2012. For example, 43% of respondents who had heard of GM food in 2002 perceived it as safe, whereas only 25% of those who had not heard of GM food did so in the same year (rows 1 and 2, Appendix C). In 2012, nearly half (49%) the respondents who had heard of GM food perceived GM food as unsafe, which was much higher than that (29%) of respondents who had never heard of GM food. These findings provide indirect evidence on the impact of rising negative media reports on consumer perceptions regarding GM food safety in recent years.

Many individual and household characteristics also have significant impacts on consumer perceptions on GM food safety. Because the results based on the whole sample (Table 4) and the subsamples (Appendixes A and B) are largely consistent, we first focus our discussions on the results presented in Table 4 and then major differences between the early period (2002–2003) and the more recent one (2010–2012).

Most of individual characteristics have significant impacts on consumers' GM food safety perception (Table 4). For example, the age of the respondent is inversely correlated to having an opinion on the safety of GM food after holding other factors constant, because the estimated coefficients for age are less than 1 in both the unsafe/no idea and safe/no idea equations (row 5, columns 2 and 3, Table 4). Males and less-educated consumers tend to trust GM food as safe for consumption more than their counterparts. Other

individual characteristic such as type of employment has little impact on consumer perceptions.

Consumer perceptions on GM food safety are also related with respondent household characteristics. Respondents from families with food allergies have a 1.492 times higher relative risk of perceiving GM food as unsafe relative to safe (column 1, Table 4). This is expected, because such respondents may be more sensitive to food safety issues. In addition, residential city size also matters. The estimated coefficient for a big city is greater than 1 and statistically significant at the 1% level (columns 1 and 2, Table 4). This implies that compared with those living in small cities, consumers living in big city are more likely to perceive GM food as unsafe for consumption. Interestingly, after controlling for the effects of other factors, we do not find a significant impact of income on consumer perceptions regarding GM food safety.

5. Discussion and conclusion

This study shows that consumers in urban China have significantly changed their perceptions on GM food safety. Compared with 10 years ago, a substantially higher number of consumers now perceive that foods produced using GM technology are not safe for consumption. On average, the percentage of consumers who perceived GM food as unsafe for consumption increased from 13% in 2002 to 45% in 2012, while the number for the consumers who perceived it as safe declined from 37 to 13% over the same period. A large amount of consumers still did not have their clear opinion on this issue: 50% in 2000 to 53% in 2010 and 42% in 2012.

The major changes on consumer perception have occurred after 2010. While the exact reasons for these changes are unknown, we expect that the increasing influence of negative media reports on GM technology and the safety of GM food may largely account for the rising concern of consumers on the safety of GM food since 2010. In addition, in recent years, the rising frequency of food safety scandals has provoked consumers' vigilance on food safety though it is unrelated to GM technology.

Our study also finds that several individual and household characteristics have significant effects on consumer perceptions of GM food safety. These include gender, education, and family members with food allergies. Because all of these variables either did not change or changed only slightly over time, their effects on the increased negative perception regarding GM food safety should be moderate. However, the differences in such perceptions among consumers at a given time are largely attributed to these individual and household characteristics.

Given that the goal of China's GM program is to boost its agricultural productivity and enhance food security (Huang *et al.* 2002, 2012), the results of this study should have significant implications for China's agricultural biotechnology in general and current ambitious GM program in particular. Increasing number of consumers who concern GM food unsafe is likely to become a major hurdle for China to continue developing and applying GM technology in the future. If China continues to significantly invest in its GM technology, more efforts may be required to popularize science and technology in general and GM technology in particular. Balancing the public debate on GM technology is also important.

Recent policy changes on GM technology suggest that the government has realized and responded to the above challenges. First, the Ministry of Agriculture of China (MOA) issued a guidance for advertisement on GM and non-GM food in January 2015, which indicated that all discriminatory advertisements for GM or non-GM food are not allowed. Immediately after this guidance, all advertisements that claimed non-GM products have disappeared. Second and more important, the No. 1 Document of 2015 from the national central government clearly stated that China will strengthen GM research, safety management and science popularization. On GM issue, this is the first time the term of "science popularization" is indicated in the national policy document, which shows the government's efforts to improve public's scientific knowledge on biotechnology and GM food. On the other hand, in response to consumer's concern, China amended its *Food Safety Law of the People's Republic of China* to include GM foods and released this amended law on April 24, 2015. This amended law states that GM food must be labelled. This is the first time for GM food to be included in the national law, which provides legal ground for government's supervision of GM food safety. While the impact of this amended law on consumers' willingness to buy GM food needs to be studied in the future. It should not be exaggerated because GM food labeling is not a new policy. Indeed, this policy has been implemented in China under the MOA's safety regulation framework for agricultural GMOs since the early 2002.

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Appendix associated with this paper can be available on http://www.ChinaAgriSci.com/V2/En/appendix.htm

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