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Does education affect consumers' attitudes toward genetically modified foods? Evidence from China's two rounds of education reforms

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Abstract

Purpose – This study analyzes the causal effect of education on consumers' cognition and attitudes toward genetically modified (GM) foods.

Design/methodology/approach – The authors propose an analytical framework to clarify the role of education levels and education content in the formation of attitudes toward GM foods and utilize education reforms in China as natural experiments to test the theoretical predictions empirically. For education levels, the authors use Compulsory Education Law's implementation to construct the instrument variable. For education content, the authors utilize the revision of the biology textbook in the Eighth Curriculum Reform to implement staggered difference-in-difference estimation. The authors use two national household surveys, the China Genuine Progress indicator Survey (CGPiS) and the China Household Finance Survey (CHFS) of 2017, combined with provincial-level data of education reforms.

Findings – The education level, instrumented by the Compulsory Education Law's implementation, has an insignificant effect on consumers' cognition and attitudes toward GM foods, whereas the acquisition of formal education on genetic science, introduced by the Eighth Curriculum Reform, has a statistically significant and positive influence.

Originality/value – This is the first study to investigate the causal effects of education level and content on consumers' cognition and attitude toward GM foods using national representative data. It is also the first to evaluate the long-term effects of the biology textbook reform in China. The findings help open the black box of how education shapes people's preferences and attitudes and highlight the significance of formal biology education in formulating consumers' willingness to accept GM foods.

Keywords Education, Genetically modified foods, Consumer attitudes, Compulsory education law, Curriculum reform

Paper type Research paper

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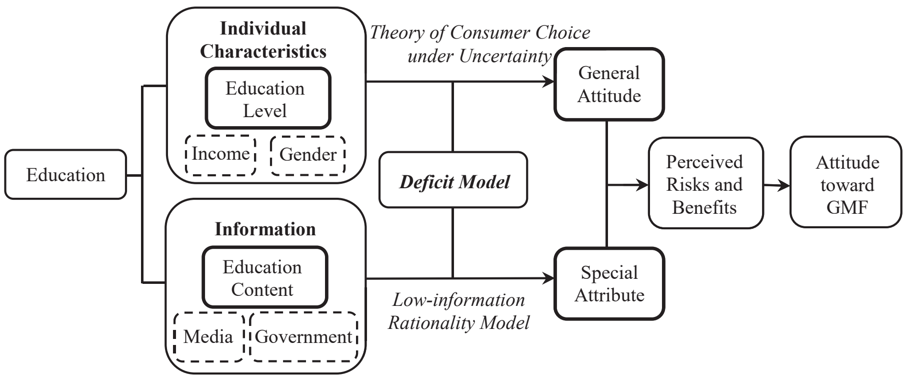
1. Introduction

Genetically modified (GM) foods, as products of emerging biotechnology, have sparked intense public disagreements (Gaskell *et al.*, 1999; Zheng *et al.*, 2017). Understanding the driving factors of consumers' attitudes toward GM foods is highly valuable for the development of agricultural policy and food market policy [1] (Qiu *et al.*, 2007; Zheng, 2015a). What can the government do to improve the science literacy of citizens and communicate better with the public on biotech issues? Education has been proven to be a long-term force in shaping human perceptions, attitudes and preferences (Meyer, 2017; Bullock, 2021). Its impact on public attitudes toward genetic modification has not been adequately studied. This paper aims to explore the causal effect of education levels and education content on individuals' attitudes toward GM foods.

The analytical framework proposed by Costa-Font *et al.* (2008) may help us understand the role of education in shaping consumers' attitudes toward GM foods. In their model, the individual characteristics and values (general attributes) and knowledge of products (special attributes) jointly guide consumers' perceptions of the benefits and risks of GM foods and shape their synergetic attitude toward the foods. Combined with price and other factors, this synergetic attitude ultimately determines their purchasing behaviors toward GM foods. Many empirical studies have noted that individual characteristics, such as age, gender, income, education level and general values about the environment, technology and culture, could affect consumers' attitudes toward purchasing GM foods (Bredahl, 2001; Hossain *et al.*, 2002; Honkanen and Verplanken, 2004; Zhong and Chen, 2008). Regarding special attributes, many studies confirm that consumers' information on GM foods can shape their attitudes (Corrigan *et al.*, 2009; Zheng, 2015b; Lu *et al.*, 2016). Here, we probe into the impact of education on consumers' attitudes toward GM foods by incorporating both education levels and education content into the framework (Figure 1). The education level, usually proxied by the number of years spent in school, could be an important attribute that affects individual consumers' general attitude toward science and technology. The education content about genetic engineering is a way of acquiring information, working as a specific attribute. Perceived risks and benefits associated with GM foods are formulated by these factors, and finally, consumers' attitudes toward GM foods are shaped.

A prevalent theory emphasizing the importance of education on improving public acceptance toward science is the "Deficit Model," which purports that the public that lacks scientific literacy tends to distrust and refuse cutting-edge technology (Durant *et al.*, 1989). An implicit assumption in this model is that increased education leads to increased scientific knowledge, and greater exposure to scientific knowledge leads to more trust in science.



Note(s): The basic framework was adapted from Costa-Font *et al*. (2008)

Figure 1. Mechanism of the influence of education on consumers' attitudes toward GM foods

However, the deficit model considers knowledge enhancement as the only channel through which education affects people's scientific attitudes and does not consider the other multidimensional impacts of education levels (Bak, 2001). Moreover, the general attitude toward science is different from specific attitudes toward applied science. More years of engagement with scientific literacy would enhance public support for general science, but not necessarily lead to increasing support for such controversial scientific issues as GM foods (Allum *et al.*, 2008). Furthermore the genetic science expertise that people possess needs to be considered when studying consumer attitudes toward GM foods. Therefore, it is necessary to distinguish between the effects of education content and education levels on people's attitudes toward GM foods and to propose possible mechanisms of these different effects in the framework by Costa-Font *et al.* (2008).

The net effect of education level on an individual's attitude toward GM foods is ambiguous. According to the classic deficit model, a higher education level could help to improve the public's general acceptance of biotechnology. However, there may be a contrary conclusion if we consider the theory of consumer choice under uncertainty, with which consumers would maximize their expected utility under budget constraints. More educational attainment is often accompanied by higher incomes, which could relax the consumer's budgetary constraint and enable them to choose more expensive non-GM foods, rather than GM foods, to avoid potential risks (Qi and Zhou, 2010). A profound disparity is also observed in the substantial empirical studies on the effect of education levels. Some research has found that consumers with relatively high education levels have a negative attitude toward GM foods (Zhong and Chen, 2008; Huang and Peng, 2015). On the contrary, others found a positive attitude that increased with consumers' education levels (He *et al.*, 2015). Nevertheless, some studies failed to show any relationship between education and consumers' attitudes toward GM foods (Qiu *et al.*, 2007; Zhang *et al.*, 2015). It is important to note that none of these studies focus on the analysis of education levels or deal with the endogeneity of education.

Regarding the content of education, there is no doubt that the deficit model still applies, and its prediction is straightforward: increased knowledge of the biological sciences will lead to greater acceptance of GM foods. There is evidence supporting the deficit model and finding that knowledge of genetics would improve consumers' willingness to accept GM foods (Lu *et al.*, 2016; McPhetres *et al.*, 2019). Besides, there are other theories on the complicated relationship between the content of education and information acquisition and utilization. One is the "Low-Information Rationality" theory, which was first proposed by Popkin (1994) and later introduced into issues about biotechnology (Brossard *et al.*, 2007). This theory emphasizes that people would use a variety of shortcuts and heuristics to save information costs for understanding biotechnology. This mode of information processing seems suitable for people who are exposed to a vast amount of information every day in the information era. Nevertheless, this does not mean that using the least costly information will lead to accurate and reliable conclusions. Mass media and social media act as the primary ways to obtain information and often contain sensational negative information on GM foods (Lin *et al.*, 2006; Zhang *et al.*, 2015; Ji *et al.*, 2019). For most people, understanding bioscience requires enormous effort. They are more likely to accept spreading negative information from the media and showing a refusal attitude toward GM foods (Zheng, 2015b).

More direct evidence suggests that people tend to support biological science and technology after gaining formal education. Earlier studies found that young students (aged 16–18 years) enrolled in science courses (Chen and Raffan, 1999) or students specializing in biology (Hill *et al.*, 1998) displayed more positive attitudes toward biotechnology. Recent studies have concentrated on the content of education and found that people possessing GM grape wine knowledge could objectively assess GM grape wine (Lu *et al.*, 2016) while gaining scientific knowledge on GM technology could lower consumers' reservations about GM foods' risk (McPhetres *et al.*, 2019). However, all of the above studies were subjected to relatively small sample sizes and weak external validity.

In summary, three noticeable gaps in the empirical literature need to be narrowed down. First, almost no studies distinguish the effect of education content from education levels on people's attitudes toward GM foods. As suggested by the above theoretical analysis, education levels and education content may function through different mechanisms. Second, the endogeneity of education is scarcely discussed in the literature on GM food consumption. To the best of our knowledge, these studies only incorporated education as a covariable, or even as a control variable (Qiu *et al.*, 2007; Zhong and Chen, 2008; Qi and Zhou, 2010; He *et al.*, 2015; Huang and Peng, 2015; Zhang *et al.*, 2015). Thus at least two issues arise that could bias the estimation of its effect. The first are the omitted variables, such as household economic conditions, which simultaneously influence education and consumers' attitudes toward GM foods. The other is reverse causality, i.e. the attitude toward GM foods may inversely affect consumers' selection of disciplines in the school. Therefore, it is necessary to seek natural experiments, such as education reforms, to identify the causality. Third, the samples in previous studies had inadequate representativeness. Given that most of these studies employed data from surveys in one or several cities (Zhang *et al.*, 2004; Qi and Zhou, 2010; Huang and Peng, 2015), or just respondents with college education level (Akbari *et al.*, 2019) and even scientists (Huang *et al.*, 2017), their conclusions are difficult to extrapolate to a more general population and inform policymaking for the government.

In this study, we used two educational reforms, the *Compulsory Education Law and* the *8th Curriculum Reform,* to identify the causal effect of education on attitude toward GM foods, combining two datasets of national representative household surveys, the *China Genuine Progress indicator Survey* (CGPiS) and *China Household Finance Survey* (CHFS), which collected data from over 40,000 households in 2017. China's *Compulsory Education Law,* which extends the minimum education level to nine years, has been promoted gradually among provinces since 1986. Therefore, we can use the variation in policy implementation at the provincial level to generate the instrumental variable (IV) for education level, which many studies have found appropriate (Fang *et al.*, 2016; Xie and Mo, 2014; Cui *et al.*, 2019). Regarding the education content, we employ the *8th Curriculum Reform,* which brought about changes in the version of biology textbooks. Compared to the textbook before the reform, the new textbook has a detailed introduction to transgenic knowledge. Whether an individual uses a new biological textbook containing transgenic technology knowledge merely depends on the new curriculum implementation time in a particular province and their year of birth. Thus, we rule out the two aforementioned endogenous issues. This empirical strategy is also used in the study of political ideology by Cantoni *et al.* (2017).

Our study contributes to the literature on GM foods in three significant ways. First, it is among the first to provide rigorous evidence of the causal impact of education on consumers' attitudes toward GM foods using national representative data. Second, it is the first evaluation of the long-term effects of biological textbook reform in China. Third, it helps us open the black box of how education shapes people's preferences and attitudes by extending the core variable from how long individuals are in school to what individuals learn in school.

The remainder of this paper is organized as follows. Section 2 introduces the study's data. Section 3 introduces the *Compulsory Education Law* and discusses the effects of education levels on consumers' cognition and attitudes toward GM foods. Section 4 investigates the *New Curriculum Reform* and demonstrates how education content affects consumers' attitudes. Section 5 concludes the paper with a discussion.

2. Data

The data employed in this study are derived from two sets of household survey data: *the* CGPiS 2017 and *the* CHFS 2017. The CGPiS is conducted by the China Institute of Innovation and Development at Beijing Normal University, investigating rural and urban households' time use, fertility, social networks, values, etc. The CHFS is conducted by the Survey and Research Center for China Household Finance at Southwestern University of Finance and Economics, focusing on households' economic and financial behaviors. Both the CGPiS and the CHFS are nationally representative surveys. The CGPiS joined the CHFS survey in 2017.

The CGPiS 2017 (and CHFS 2017) covered 29 provinces (excluding Xinjiang, Tibet, Hong Kong, Macao and Taiwan) and 355 districts/counties in China and interviewed 40,011 households in 1,428 communities. A total of 25,142 respondents were retained after we constrained the age between 16 and 60 years. The stratified and probability-proportional sampling methods employed in the surveys guaranteed randomness and representativeness. The CGPiS 2017 recorded the respondents' cognition and attitude toward GM foods for the first time in a national household survey. Other variables were primarily derived from the CHFS 2017.

The dependent variables were the consumers' cognition and attitudes toward GM foods. The consumers' cognition (*Know*) was a binary variable, defined as "know about GM foods or not" (Table 1). A total of 55.38% of the respondents reported that they knew about GM foods [2]. Attitudes toward GM foods (*Attitude*) were inquired for respondents who knew about GM foods. Among the 13,924 respondents, 54.45%, 23.52% and 22.03% chose "I refuse to buy GM foods (*Attitude = 0*)," "I do not like and do not believe the non-GM label on the goods (*Attitude = 1*)," and "I do not mind GM foods (*Attitude = 2*)," respectively. A higher value of *Attitude* means that consumers were more willing to accept GM foods.

Variables	Definition	Obs	Mean	Std. Dev.	Min	Max
GM food variables						
Know	Know about GM food = 1, otherwise = 0	25,142	0.554	0.497	0	1
Attitude	Acceptable level (0, 1, 2)	13,924	0.676	0.812	0	2
Education variables						
Schooling	years of schooling[a]	25,281	10.109	4.098	0	22
PostReform	New curriculum reform = 1, otherwise = 0	9,672[b]	0.126	0.332	0	1
TransPeriod	Transitional period = 1, otherwise = 0	9,672	0.156	0.363	0	1
Control variables						
Age	years of age	25,284	44.749	10.748	16	60
Married	Married = 1, otherwise = 0[c]	25,114	0.912	0.283	0	1
Rural	Rural residents = 1, urban residents = 0	25,284	0.300	0.458	0	1
Male	Male = 1, female = 0	25,284	0.471	0.499	0	1
CPC[d]	CPC member = 1, otherwise = 0	25,284	0.095	0.293	0	1
Family size	Number of family members	25,284	3.457	1.466	1	13
Income	Annual household income (RMB yuan)[e]	25,284	104,858	222,683	0	5,000,000
Health	Poor = 1 (2.50%), fair = 2 (11.89%), average = 3 (32.36%), good = 4 (36.60%), excellent = 5 (16.65%)	25,283	3.530	0.985	1	5

Note(s): [a]The CHFS only records correspondents' education level, and the schooling years are assigned by their education level. [b]The new curriculum reform is oriented to senior high school, so the sample here is limited to those with senior high school education or above. c. It takes the value of 1 if the marriage status is married, divorced, separated without a legal divorce and remarried and 0 otherwise (unmarried or cohabiting). d. CPC is an abbreviation for the Communist Party of China. e. Respondents whose annual family income was less than zero were censored to 0. In logarithmic processing, we add one to zero income, making these logarithm values equal to 0

Source(s): The CGPiS and CHFS in 2017

Table 1.
Descriptive statistics

Education level was measured by the number of years spent in school. The average number of years in school for the entire sample was 10.11, slightly higher than nine years for junior middle school graduation required by China's compulsory education policy. Education content was represented by whether an individual had experienced the new curriculum reform (*PostReform*) or the transitional period (*TransPeriod*). The details of these two policy variables are introduced in section 4. Approximately 12.6% of the population with high school education or above went through the new curriculum reform, and 15.6% were in the transitional period.

The sample was even on gender (males accounted for 47.1%), with an average age of 44.75 and a high proportion of marriage (93.9%). Approximately 30% of the respondents were rural residents. The households had an average of 3.46 family members and an annual income of 104,858 RMB yuan in 2017. In the regression, we used the logarithmic form of *income*.

3. Effects of education levels on cognition and attitudes toward GM foods

3.1 The reform of compulsory education law

China promulgated the *Compulsory Education Law* in 1986. It stipulated that children aged over six years must attend school for a nine-year compulsory education [3]. In 1992, the 14th National People's Congress of China declared that, "education must be in the strategic position of priority development." According to China's Education Reform and Development Outline (1993), a 9-year compulsory education was expected to be fully implemented in China by 2000. Despite the enactment of the law on July 1, 1986, the actual implementation time varied across provinces. Nearly half of the provinces implemented the policy in 1986, whereas the rest implemented it in subsequent years, toward the end of 1994 [4].

Several studies have used this reform to construct instrument variables to estimate the impact of education levels on the return on investment in education and health (Trostel *et al.*, 2002; Fang *et al.*, 2016; Xie and Mo, 2014; Torun, 2018). An instrument variable should satisfy two requirements, uncorrelated with other unobservable factors affecting the dependent variable and strongly correlate with the endogenous independent variables. For the first requirement, the variation of exposure to Compulsory Education Law is driven purely by the timing of law enforcement at the provincial level and birth year of the individual in question. It could hardly relate to omitted variables, such as family background and individual learning motivation. Therefore, it may hardly affect consumers' cognition and attitudes toward GM foods through other channels but may prolong the years of education.

For the second requirement, the dropout rates of preliminary and junior middle schools are strictly monitored and may correlate with the salary and promotion of local education authority after the implementation of the Compulsory Education Law. Therefore, parents who allow their children to drop out of school would face much greater pressure than before. We make a simple comparison to show the correlation between the implementation of Compulsory Education Law and individuals' years in school. The 9-year compulsory education requires children to enroll in primary school at six. Therefore, they are expected to graduate from junior middle school at fifteen. Thus, we take individuals aged 15 or below when the policy is implemented as the treatment group. Individuals aged 16 and above are the control group. Table 2 shows that the average years in school in the treatment group were 11.51 years, nearly 2.5 years more than those in the control group (9.02). Considering the increasing trend in years spent in school, we narrowed the age bandwidth to two years; that is, we compared the average years in school of individuals aged 14 and 15 and individuals aged 16 and 17 at the law's effective date. Table 2 shows that the average years in school for the two-year-bandwidth treatment group were 9.65 years, which is higher than that of the control group (9.20). The pattern still held when we compared a five-year-bandwidth treatment group (11–15 years old) with a five-year-bandwidth control cohort (16–20 years old). The average number of years in school for the five-year-bandwidth treatment cohort was 9.85, while that of the control group was 9.0.

We generated an IV representing the exposure to compulsory education law at the individual level. The specific value of this IV was generated based on a province's policy implementation year and an individual's birth year. Following Li and Zhang (2017), we assumed that moving down to a younger age would strengthen the effect of compulsory education. Thus, we created a discrete variable *ExpoLaw* and assigned a value of 0–9. If individual i aged 16 or above when the compulsory education law in province p was implemented, it was assumed that they were not affected by the policy, and *ExpoLaw* took the value of 0. If individual i had just reached the school enrollment age (7 years old or below) at the provincial policy implementation date, it was assumed that they were fully affected by the policy; therefore, *ExpoLaw* took the value of 9. The values of *ExpoLaw* for individuals aged 8–15 when the policy was implemented decreased from 8 to 1. For example, *ExpoLaw* took a value of 6 for those aged 10 years when the education law was implemented.

3.2 Econometric specification

We first used a probit regression model, Eq. 1, to examine the effect of education levels (years in school) on respondents' cognition of GM foods. $Know_i$ was a binary variable defined as whether respondent i knew the GM foods. *Eq.2* investigated the effect of education level (years in school) on respondents' attitudes toward GM foods using the ordered-probit model. $Attitude_i$ was a ternary variable with values of 0, 1, or 2. $\boldsymbol{X}_i$ was the vector of control variables, including age, gender, region (rural or urban), CPC membership, marital status, number of family members, the logarithm of annual household income and self-reported health status. We also added the province fixed effects $\sum_p \delta_p$ in the regression to control for the high disparity among regions. ε_i was the error term.

$$Know_i = \alpha_1 + \beta_1 Schooli gn_i + \gamma_1' \boldsymbol{X}_i + \sum_p \delta_p + \varepsilon_{1i} \tag{1}$$

$$Attitude_i = \alpha_2 + \beta_2 Schooli gn_i + \gamma_2' \boldsymbol{X}_i + \sum_p \delta_p + \varepsilon_{2i} \tag{2}$$

As mentioned before, the years of schooling (*Schooling*) could be endogenously resulting from unobserved missing variables, or reverse causation. Therefore, we employed individuals' exposure to compulsory education (*ExpoLaw*) as an instrument with the IV-probit or IV-ordered-probit model.

3.3 Empirical results

The probit estimation illustrates the positive effect of the level of education on consumers' cognition of GM foods, which is statistically significant at the 1% level (Column 1, Panel A, Table 3). The marginal effect (ME) is reported in Panel B. As shown in Column 1, Panel B of Table 3, the estimated ME of *Schooling* indicates that the probability that the respondent knows about GM foods would rise by 4.2% if the number of years in school increases by one.

	All		Two-year bandwidth		Five-year bandwidth	
	Control	Treatment	Control	Treatment	Control	Treatment
Mean	9.02	11.51	9.20	9.65	9.00	9.84
Observations	14,256	11,025	1,767	1,537	4,392	3,397

Source(s): The CHFS in 2017

Table 2. The years in school for individuals in the treatment and control groups

Variables	Probit Know (1)		Ordered-probit Attitude (2)
Panel A: Coefficients			
Schooling	0.149*** (0.003)		−0.011*** (0.004)
Age	−0.019*** (0.001)		−0.019*** (0.001)
Male	−0.061*** (0.019)		0.081*** (0.021)
Rural	−0.481*** (0.022)		0.103*** (0.032)
CPC	0.168*** (0.036)		−0.007 (0.031)
Married	0.308*** (0.042)		−0.340*** (0.038)
Familysize	−0.059*** (0.007)		−0.012 (0.009)
Log (income)	0.052*** (0.005)		0.011** (0.005)
Fair health	0.021 (0.067)		0.014 (0.107)
Average health	0.213*** (0.063)		−0.010 (0.101)
Good health	0.258*** (0.064)		−0.032 (0.101)
Excellent health	0.257*** (0.067)		−0.046 (0.103)
Provincial FE	Yes		Yes
Observations	24,972		13,808
Pseudo R^2	0.273		0.036
Panel B: Marginal effects			
Schooling	0.042*** (0.001)	Attitude = 0	0.004*** (0.001)
		Attitude = 1	−0.001*** (0.000)
		Attitude = 2	−0.003*** (0.001)

Note(s): (1) Coefficients are reported in Panel A and marginal effects of school in Panel B. (2) For health status, "poor health" is set as the baseline group; (3) Standard errors are reported in the parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively

Table 3.
Estimated effects of education levels on cognition and attitude of consumers toward GM foods with probit/ ordered-probit regressions

Regarding control variables, the younger people, the females, the urban residents, the CPC members, the married and those with higher household income are likely to report that they know about GM foods. People in average health, or above, were more likely to know about GM foods than those in poor health.

However, education levels have a statistically significant and negative influence on respondents' attitudes toward GM foods (Column 2, Panel A, Table 3), which indicates that the population with more years in school is more likely to refuse GM foods than those with fewer years in school. Similarly, we calculated the MEs (Columns 2 Panel B, Table 3). The results show that for every additional year of school, the probability of consumers rejecting GM foods would rise by 0.4%, and the probability of accepting GM foods would decrease by 0.3% significantly. As for the control variables, the older and married population tends to refuse GM foods, whereas male and rural residents tend to accept it. Consumers with higher household incomes are more likely to accept GM foods. Meanwhile, CPC membership, number of family members and health status have insignificant effects on the respondents' attitude toward GM foods.

Table 4 reports the result of IV-probit and IV-ordered-probit estimation using individuals' exposure to compulsory education as an instrument variable. The first-stage regression results (Columns 1 and 3, Panel A, Table 4) show that *ExpoLaw* is not a weak IV. The estimated coefficients of *ExpoLaw* are 0.078 and 0.056, respectively, and both are statistically significant at the 1% level. The second-stage regression (Column 2, Panel A, Table 4) shows that the year of schooling has an insignificant effect on respondents' cognition about GM foods. Meanwhile, the year of schooling has an insignificant influence on respondents' willingness to accept GM foods (Column 4, Panel A Table 4). We reported the MEs of the second phase of *Schooling* in Panel B, and no significant effects are found either.

Variables	IV-probit Know (1) Stage 1	(2) Stage 2	IV-Oprobit Attitude (3) Stage 1	(4) Stage 2
Panel A: Coefficients				
ExpoLaw	0.078*** (0.012)		0.056*** (0.014)	
Schooling		−0.022 (0.077)		−0.009 (0.018)
Panel B: Marginal effects				
Schooling (stage 2)		−0.006 (0.021)	Attitude = 0	0.006 (0.007)
			Attitude = 1	−0.016 (0.018)
			Attitude = 2	−0.004 (0.005)
Controls	Yes	Yes	Yes	Yes
Observations	24,096	24,096	13,808	13,808

Note(s): (1) Coefficients are reported in Panel A and marginal effects of schooling in Stage 2 are reported in Panel B; (2) Control variables include age, gender, region (rural or urban), CPC membership, marital status, number of family members, the logarithm of annual household income and self-reported health status; and (3) Standard errors are reported in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively

Table 4. Estimated effects of education level on cognition and attitude of consumers toward GM food with IV-probit/IV-oprobit regressions

Several factors may account for the insignificant effect of education level on consumer attitudes. First, the IV estimation rules out the influence of omitted variables, which are confounded with, and usually mistaken for, the effect of education level. In addition, compared with general science, education levels are less likely to explain properly a people's acceptance of controversial issues like GM foods, as stated in our theoretical framework.

4. Effects of education content on the cognition and attitudes toward GM foods

4.1 The new curriculum reform

The formal knowledge of genetic science acquired by consumers may initially come from biology courses in schools. In China, teachers must strictly follow the teaching materials designated by the provincial education authorities. High school students acquire this knowledge from textbooks under their teachers' instructions and consolidate it repeatedly through exercises prepared for the college entrance examination (*gaokao*). However, the content of biology textbooks changed, ascribing to the rounds of curriculum reforms initiated by China's Ministry of Education, which provide a quasi-experiment for us to identify the effects of education content.

The Eighth Curriculum Reform (*also known as* the New Curriculum Reform) was initiated in 2004 for senior high school. Before the reform, the biology textbook for senior middle school did not contain genetic engineering knowledge. The Eighth Curriculum Reform added a new chapter with a comprehensive introduction on genetic engineering and GM foods. The revised book was used by senior middle school students in their first year. Hence, the students who attended the senior middle school after the Eighth Curriculum Reform would certainly receive formal knowledge of genetic science. Meanwhile, the new curriculum reform puts forward higher requirements for students to understand biotechnology's development than before [5].

The new curriculum reform's staggered implementation across different provinces enables us to identify the causal effects. Whether individuals use a revised textbook containing GM foods knowledge relies only on the policy's implementation year. The individual's year of birth and years in school are irrelevant to the unobserved missing variables of family background, individual capacity, motivation, etc. We gathered information on the biological science and technology of each province's biology textbook and recorded the time at which each province initiated the curriculum reform [6].

We generated a binary variable, *PostReform*, to represent whether the respondent was enrolled in senior middle school after the Eighth Curriculum Reform. Although the exact time of individuals' high school registration is unavailable, the year when the respondents received high school education [7] can be inferred according to respondents' age and school enrollment rules in China. A student who attended primary school at the age of six enrolls in senior middle school at 15. If the respondent entered senior middle school after the Eighth Curriculum Reform, the *PostReform* is assigned a value of 1 and otherwise 0. In addition, there is a transition period before the formal implementation of the new curriculum. The biology textbooks were regularly updated for teaching trials since 2000. The textbooks used in this transition period contained a brief introduction of knowledge of genetic engineering but did not provide a specific explanation of GM food. Acknowledging the possible effect of these teaching trials on respondents' acquisition of GM knowledge, we denote the period from 2000 to the year when each province initiated the reform as the transition period. We created a binary variable *TransPeriod* and assigned a value of 1 if the person attended senior middle school during the transition period and 0 otherwise. Finally, the period before the transition period is marked as the pre-reform period, represented by the dummy variable *Pre-reform*.

Table 5 presents consumers' cognition and attitude toward GM food who joined the senior middle school in different periods. The percentage of respondents who entered senior middle school in the post-reform period (84.75%) or the transition period (87.38%) is significantly higher than that in the pre-reform period (79.54%). Thus, the new curriculum reform is likely to increase consumers' cognition of GM food. Regarding attitudes towards GM foods, 26.07% of the consumers who joined the senior middle school in the post-reform period refused to buy GM food. This is much lower than the proportion of the ones in the pre-reform period (60.96%). Meanwhile, 50.78% of the consumers who joined the senior middle school during the post-reform period were willing to accept GM food, significantly higher than those during the pre-reform period (15.46%) or the pre-reform period (30.42%). Therefore, the new curriculum reform seems to improve respondents' willingness to accept GM food. Nonetheless, an econometrical analysis is necessary to examine the causal effect of education content on consumers' attitudes toward GM foods.

4.2 Econometric specification

To investigate the effect of the formal education of genetic science on consumers' cognition of GM foods, *Eq. 3* specifies a probit model using a staggered difference-in-difference:

Table 5. Proportions of the cognition and attitude toward GM foods for consumers who joined the senior middle school over different periods (%)

		Period		
	Total	Pre-reform	TransPeriod	Post-reform
Cognition				
Unknow	18.58	20.46	12.62	15.25
Know	81.42	79.54	87.38	84.75
Attitude				
"I refuse to buy GM foods."	54.30	60.96	37.87	26.07
"I do not like and do not believe the non-GM label on the goods."	23.97	23.58	31.71	23.15
"I do not mind GM foods."	22.59	15.46	30.42	50.78

Note(s): The sample sizes of cognition and attitude are 9,636 and 7,848, respectively

$$Know_i = \alpha_3 + \beta_3 Post\ Reform_i + \beta_4 TransPeriod_i + \gamma_3' \boldsymbol{X}_i + \sum_p \delta_p + \sum_b \tau_b + \varepsilon_{3i} \quad (3)$$

where $Know_i$ represents whether individual i knows the GM foods. Both $Post\ Reform_i$ and $TransPeriod_i$ are binary variables representing whether the respondent joined the senior middle school after the new curriculum reform and in the transition period, respectively. β_3 and β_4 capture the effects of the new curriculum reform on consumers' cognition of GM foods. In addition to the control variables $\boldsymbol{X}_i$ and provincial fixed effects $\sum_p \delta_p$, we also add the fixed effect of birth year $\sum_b \tau_b$ to control the time trend.

An ordered-probit model is then specified in Eq. 4 to analyze the effect of education content on consumers' attitudes toward GM foods. The coefficients of interest β_5 and β_6 represent the effects of new curriculum reform (post-reform and transition periods, respectively) on consumers' attitudes toward GM foods.

$$Attitude_i = \alpha_4 + \beta_5 Post\ Reform_i + \beta_6 TransPeriod_i + \gamma_4' \boldsymbol{X}_i + \sum_p \delta_p + \sum_b \tau_b + \varepsilon_{4i} \quad (4)$$

4.3 Empirical results

First, we report the estimation results of Eqs. (3) and (4) in Panel A of Table 6. Column 1 shows that the estimated MEs of *PostReform* and *TransPeriod* are positive and statistically significant (0.163 and 0.172, respectively), illustrating those individuals attending senior middle school in the transition or reform period had a 16.3 and 17.2% higher probability of knowing about GM foods than the base group before the reform. As for attitude, Column 2–4 in Panel A of Table 6 demonstrate that the new curriculum reform could significantly enhance people's willingness to accept GM foods. Experiencing the new curriculum reform could reduce the probability of consumers refusing GM foods ($Attitude = 0$) and increase both the probability of people doubting ($Attitude = 1$) or accepting ($Attitude = 2$) GM foods. All these effects were statistically significant at the 1% level.

Variables	Probit Know (1)	Attitude = 0 (2)	Oprobit Attitude = 1 (3)	Attitude = 2 (4)
Panel A: Full sample				
PostReform	0.163*** (0.046)	−2.046*** (0.091)	0.537*** (0.030)	1.508*** (0.068)
TransPeriod	0.172*** (0.052)	−2.081*** (0.096)	0.546*** (0.031)	1.535*** (0.072)
College	0.116*** (0.009)	0.011 (0.012)	−0.003 (0.003)	−0.008 (0.009)
Observations	9,528	7,765	7,765	7,765
Panel B: Subsample of individuals born after 1975				
PostReform	−0.014 (0.043)	−1.938*** (0.094)	0.253*** (0.027)	1.685*** (0.083)
TransPeriod	−0.006 (0.047)	−1.977*** (0.099)	0.258*** (0.027)	1.719*** (0.087)
College	0.086*** (0.011)	−0.008 (0.018)	0.001 (0.002)	0.007 (0.016)
Observations	4,766	4,195	4,195	4,195
Control variables	Yes	Yes	Yes	Yes
Provincial fixed effect	Yes	Yes	Yes	Yes
Birth year fixed effect	Yes	Yes	Yes	Yes

Note(s): (1) Marginal effects are reported. (2) Standard errors are reported in parentheses. ***, ** and * represent statistical significance at the 1%, 5% and 10% levels, respectively. (3) Control variables include age, gender, region (rural or urban), CPC membership, marital status, number of family members, logarithm of annual household income and self-reported health status

Table 6. Estimated effects of the new curriculum reform on consumers' cognition and attitude toward GM foods, with probit/oprobit regressions

Since we restricted the sample to senior middle school attendance, one concern was that the revised textbook's effect might conflate the rising probability of college entrance if the rollout of the Eighth Curriculum Reform coincided with the expansion of higher education. We incorporated a variable *College*, which was defined as whether the individual had attended college or not. The estimated ME of *College* in Column 1, Panel A, was significantly positive, which indicated that college education and formal knowledge of genetic science acquired in middle school jointly affected respondents' cognition of GM foods. Regarding consumers' attitudes, the ME of *College* was statistically insignificant in Column 2–4, Panel A, Table 6. This is consistent with the findings in section 3 that education level did not affect attitude toward GM foods.

Moreover, the sample covered respondents with a broad range of birth years; therefore, the effect of the new curriculum reform may confound with other factors varying with birth cohort. Accordingly, we restrict the sample to the subgroup of those who joined the senior middle school after 1990 (those born after 1975) and show the probit and ordered-probit regression results in Panel B of Table 6. The results in Column 1 indicate that for people born after 1975, the new curriculum reform no longer had a significant effect on their knowledge of GM foods. There may be some explanations for these results. Schooling was not the only way to obtain genetic engineering knowledge. Younger consumers could, for example, access information from relatively extensive sources due to wide access to the internet. As for attitude, *PostReform* and *TransPeriod* still had positive and statistically significant coefficients in Columns 2–4 of Panel B in Table 6.

5. Conclusion and discussion

Utilizing data from two national representative household surveys in China, this study investigated the effects of education on consumers' cognition and attitude toward GM foods. We found that education levels had no statistically significant effect on consumers' cognition of GM foods and their attitude toward them. However, the education content had a statistically significant and positive effect on consumers' willingness to accept GM foods.

These findings are consistent with the predictions of both the extended deficit model and the low-information rationality model. The deficit model's conventional suggestion of increasing general scientific literacy (i.e. education level) may not contribute much to raising support for controversial scientific issues. However, its emphasis on imparting more knowledge about GM foods to the public (education content), especially through formal education processes, is meaningful for promoting GM acceptance. In addition, as the low-information rationality theory predicts, it is rational for consumers with formal education on GM foods to avoid looking for extra information from the media. Meanwhile, those without formal genetic education will consider looking for in-depth transgenic knowledge time-consuming. Accordingly, they may be more likely to follow others and become conservative and irrational about GM foods. In other words, whether people have accepted education on transgenic knowledge could determine their different *ex ante* beliefs and thus differentiate their *ex post facto* attitudes from each other (Huffman *et al.*, 2007).

Formal education on genetic science has persistent and far-reaching effects on consumers' attitudes toward GM foods. As the new curriculum reform in China was initiated in 2004, more than 10 years earlier than the survey time (2017), the surveyed consumers were inevitably affected by the potential negative information on GM foods from social media. However, consumers who received formal education on genetic science still displayed a positive attitude toward GM foods than those who did not.

This study offers policy implications for improving citizens' bioscience literacy and raising public acceptance of genetic engineering. Indeed, it is necessary to strengthen the formal education of basic knowledge on GM foods and genetic engineering. This could be achieved by updating biology curriculums and textbooks, which could shape consumers' subjective cognition of GM foods and enhance their understanding of biotechnology's safety and economic benefits. In addition, our findings could help to assess market demand for GM products in China more accurately. Although the deep concerns among consumers have slowed down the commercialization pace of GM agricultural products, there is reason to be optimistic about the future of GM commodities, as more young people with formal biotechnology education are becoming the mainstay of food consumption.

Notes

1. Despite China's first commercial cultivation of GM crops in 1996, GM crops' harvest area covered only 2.9 million hectares by 2018, accounting for 1.51% of global harvest areas for GM food (ISAAA, 2019).
2. Our sample includes the rural areas. This explains why the proportion of people knowing about GM foods in this paper was lower than Zheng (2015b) and He *et al.* (2015), which only sampled urban areas.
3. The enrolling age in areas with unsatisfactory school facilities could be deferred until age 7.
4. Details of the implementation of the Compulsory Education Law are available upon request to authors.
5. The previous syllabus only required students to "understand and focus on the application of biological knowledge in life, production, science and technology development and environmental protection," while the objectives of the new curriculum required students to "be involved in biological science knowledge dissemination, promote biological science knowledge into personal and social life".
6. Details of the implementation of the New Curriculum Reform are available upon request to authors.
7. We carefully identified the individual's province of high school attendance. The default province of high school attendance is the household registered (*hukou*) province. For those living outside their *hukou* province during high school, the actual province of residence at the time served as the province of high school attendance. For those who experience inter-provincial migration after high school, their pre-migration location was recognized as the place of high school attendance. In total, 2,600 observations were corrected for high school attendance province.

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