What Factors Influence Producers' adoption of Transgenic Technology under the Background of Risk Amplification?

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Abstract: Consumer preference for products made from transgenic technology has been widely studied, yet few studies exist exploring the factors influencing producers' adoption of transgenic technology. Based on field surveys in Chinese provinces of Shanxi, Henan and Shandong, we employed a gambling experiment to capture producers' risk preferences by estimating their risk aversion coefficients. We further estimated producers' risk amplification and risk perception of GM technology. Using ordered logit model, we identified the major factors influencing producers' adoption of transgenic technology. We found the factors impacted the decision of producers from different regions in different ways. The results showed that two-thirds of participants amplified the risk of transgenic crops. When there was potential risk, producers might not be rational even if they had high level of knowledge and cognition about the technology. Our results shed light on government policies aiming to increase the adoption of new technologies by producers.

1. Introduction

Innovation and reform promote economic and societal development, but it is often accompanied by uncertainty and risk [11]. According to the society amplification framework of risk (SARF), the risk of events can be amplified through government authority, expert opinions, traditional mass media, relatives and friends and other channels [6]. This "groundless worry" behavior will hinder the effectiveness of market or policy interventions, which can slow down product or technology adoption and even the speed of economic growth [9]. As a topic most closely related to people's health, the risk of food safety is very easy to be amplified. Using SARF, Lee et al. (2020)[7] studied consumers' risk perception and willingness to pay for genetically modified food. This paper uses transgenic crops as an example product to investigate the factors influencing producers' adoption of new technologies under risk amplification. In the 1990s, transgenic cash crops such as insect-resistant cotton were introduced into in China's Henan and Shandong provinces and achieved great success [3]. China has carried out transgenic research for crops and developed transgenic varieties. However, few varieties be commercialized on a large scale.

On one hand, the safety of genetically-modified (GM) food is questioned by some consumers. When BT-gene is transferred to corn, cry9c protein with strong sensitization will be produced. Eating this type of corn will cause food allergy symptoms of headache, diarrhea, nausea and vomiting [1]. Lusk and Coble (2005)[8] found that the higher the degree of risk aversion, the less likely for consumers to adopt new technologies. Therefore, consumer demand affects farmers' production activities, so risk-averse producers may amplify the risk of GM crops.

On the other hand, the advantages of transgenic crops are reflected in several aspects. First, much evidence has shown transgenic technology increases crop yields. There has also been much success with crop varieties that are drought and cold resistant [10]. Second, economic benefits and low planting cost have been shown [4]. Third, transgenic BT cotton reduces the use of pesticides by more than 60% [5], which greatly reduces the adverse impact of pesticides on farmers' health. Fourth, the planting requirement of transgenic crops is similar to that of traditional crops. The benefits of GM crops to farmers are generally greater than to consumers, so producers should be willing to grow them. Risk aversion is an important factor hindering the extension of agricultural technology [2]. Therefore, transgenic crops are a very suitable product to understand producers' adoption behavior under risk amplification.

With the increasing need for technology innovation to increase productivity, the "risk" of technologies has been drawing more attention and is likely to be amplified. Based on the risk amplification degree and risk preference of Chinese producers for GM crops, this paper explores the major factors influencing producers' adoption of new technologies. Specifically, we aim to find answers the following questions: Are producers' perceived risks of GM crops amplified? What are the factors influencing producers' adoption of GM crops? What the government can do to speed up the new technology adoption by producers? Using data collected through field experiments

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with producers in three Chinese provinces this study measures producers' risk aversion degree, explores the impacts of producers' risk amplification, individual characteristics, risk cognition and preference on their adoption of transgenic technologies.

2. Producer survey and experiment design and implementation

2.1 Experimental design

After dropping unusable questionnaires, 338 valid questionnaires were used in this analysis, including 95 participants in Henan, 149 participants in Shanxi, and 94 participants in Shandong. Each participant who completed the survey received 5 yuan, plus the earnings from lottery series in the gambling experiment.

The questionnaire consisted of three sections: The first section is about individual and household characteristics. Participants need to answer eight questions about household and individual information. Before filling in the questionnaire, the experiment moderator repeatedly stressed that the information obtained was completely confidential and only used for academic research, to obtain real information. The second part included multiple-choice questions on consumption habits, genetic knowledge, and attitude towards the risk of GM technology, risk perception and the acceptance of GM agricultural products. Participants were told in advance that there was no right or wrong choice for these questions. The third part consisted of the gambling experiment. To help participants better understand the gambling experiment, two moderators provided detailed explanations about how the experiment would work and answered questions related to mechanism of the experiment. Because participants did not know which lottery will be drawn in advance, this experimental method made participants pay attention to each choice and were more likely to reveal their true preferences. This experiment will be described in detail in the next section.

2.2 Gambling experiment

In the gambling experiment, participants needed to answer questions in the following form:

"I choose lottery A from line 1 to line n"; "I choose lottery B from lines n to 14."

Under the hypothesis of rationality of economics, in each series, participants can only switch from option A to option B once, or would not switch at all (only choose A or only choose B). [1] The return of option A is same(in series1-"get 8 yuan with 30%,get 2 yuan with 70%"; in series2-:get 8 yuan with 90%,get 6 yuan with 10%"). The return of option B is increasing: In series 1, when moving down, the return with small probability is increasing (get 0.5 yuan with 90%,get 10 yuan with 10%- get 0.5 yuan with 90%,get 100 yuan with 10%); in series 2, when moving down, the return with high probability was increasing(get 0.5 yuan with 30%,get 9 yuan with 70%- get 0.5 yuan with 30%,get 35 yuan with 70%).

3. Empirical analysis

3.1 Dependent variable selection

The dependent variable was the acceptance of genetically technology and the willingness to purchase GM crops. Building upon Lusk (2005)[8], we developed questions about the acceptance of genetically technology using five Likert-scale statements. Participants chose "strongly disagree", "disagree", "neutral" "agree", or "strongly agree" based on their levels of agreement to these statements. For each participant, a score was generated by taking the mean of these five variables and rounded to integer of five levels: 1, 2, 3, 4, and 5. A higher score indicates a higher level of willingness to grow and the acceptance of GM agricultural products.

3.2 Explanatory variables selection

(1) The degree of risk amplification of GM crops（ra）. Participants were asked to rank the following five hazards from high to low according to their perceived harmfulness of these five items.[2]The scientifically proved harm of GM agricultural products was the smallest among these five hazards. If it was ranked first, the risk amplification is recorded as 4; by analogy, if ranked fifth, the risk amplification is recorded as 0. The greater the value, the higher the degree of risk amplification.

(2) The relative risk preference coefficient*(rr).* The larger the value, the more risk averse. We assume the producer has the utility function as following:

$$U(x,p;y,q)=\begin{cases} v(y)+\pi(p)\big(v(x)-v(y)\big); x>y>0 \\ \text{Or } x<y<0 \\ \pi(p)v(x)+\pi(q)v(y); x<y<0 \end{cases} \quad (1)$$

$$v(x)=\begin{cases} x^{1-\sigma};\ x>0 \\ -\lambda\,(-x)^{1-\sigma};\ x<0 \end{cases} \quad (2)$$

$$\pi(p)=exp[-(-Ln(p))^{\alpha}] \quad (3)$$

$U(x,p;y,q)$ is producers' utility function, $v(x)$ is value function, x is the high income obtained by the producer when the "unexpected luck" occurs, y is the low income obtained when the "unexpected luck" does not occur, p is the probability of obtaining the high income, and q is the probability of obtaining the low income. $\pi(p)$、$\pi(q)$ are weights of two probabilities in the utility

[1] We dropped the observations in which participants switched between options A and B repeatedly.

[2] Simple and understandable examples - "excessive preservatives" and "moldy rice" are given in " food additives that exceed the regulatory limit " and " bacteria infected food and expired food," respectively.

function. σ 、 λ 、 α represent three risk preference coefficients. $1-\sigma$ measures the curvature of the value function; the higher value, the lower the producer's willingness to take risks. σ the higher the value, the greater the negative utility brought by the loss than the positive utility brought by the same amount of gain, and the lower the producers' willingness to take risks. α is the attraction of "unexpected luck" to producers. λ means the higher the value, the lower the willingness to take risks.

The calculation of relative risk preference coefficient follows the formula of Lusk (2005): $U（x）=x^{1-rr}/(1-rr)$，indicates the utility of a benefit. The range of relative risk preference coefficient is calculated using MATLAB2016 software.

(3)The risk perception of GM technology（rp）. 1-5，the higher the score, the stronger the risk perception. Seven statements were presented to participants, participants were asked to indicate their degree of agreement to these statements using a Liker-scale with 1 meaning "strongly disagree" and 5 meaning "strongly agree." The mean of these variables was used to measure producers' risk perception of GM technology.

(4)Demographic variables:

Gender-dummy variable, male=0，female=1; *age* -continuous variable, 13-70 years old; *marry*-dummy variable, unmarried =0， married =1)； *nm*-continuous variable, number of people in the household; *under7* -If there are children under 7 years old in the household, dummy variable-no=0， yes=1; *byond60* -If there are elderly people beyond 60 years old in the household, dummy variable, no=0，yes=1; *edu* -categorical variable, 1-5 education level; *mhi*- categorical variable, 1-10 levels, monthly household income.

(5) Other control variable:

char -If a participant was in charge of purchasing food, no=0，yes=1; *freq*-the higher the score, the lower the frequency to read date of manufacture,1-5; *trust* - the higher the score, the higher the trust in Chinese food industry,1-5; *cog*-the higher the score, the higher cognition of GM,0-5; *atti* -the higher the score, the more negative the attitude towards GM,1-5; *knowl* -the higher the score, the richer the genetic knowledge,0-4; *label*-GM products must be labeled, dummy variable, no=0，yes=1.

4. Full sample estimation results

Table 1 reports the full sample estimation results of how different factors impact GM crop acceptance by producers. Among them, columns 2-3 are the estimation results of the whole sample using ordered logit models, columns 4 and 5 show Poisson model estimation results. Compared to model 1 and 3, model 2 model 4 add two interaction items, *ra*trust* and *label * cog*. The results show that three core risk-related explanatory variables, two demographic variables, four other control variables and two interactive items significantly affect the acceptance of GM agricultural products by producers.

4.1 Estimation results

4.1.1 Ordered logit estimation results

(1) The two variables, relative risk coefficient (*rr*) and risk perception (*rp*), have significantly negative impacts on GM acceptance, that is, participants who are more risk averse and with higher perceived risks of GM agricultural products are less likely to accept GM crops. The results are consistent across the two models and the coefficients are highly significant. Thus, the null hypothesis 1 cannot be rejected. Most of the coefficients of demographic variables and the interaction terms are not significant. The results are intuitive because the more conservative the attitude towards transgenic crops, the lower the acceptance of them. Producers' risk preferences affect their decisions to a great extent. This indicates producers' risk amplification might lead to irrational decisions in the adoption of GM crops.

(2)We found that participants who read information on packages when buying food had a low acceptance of GM agricultural products. The coefficients of *freq* are significant and are consistent across the two models. The coefficient of *char* is significantly positive. Because participants in charge of household food purchase had more responsibility for food safety of their households, their acceptance of GM crops is significantly lower than that of participants who were not in charge. Participants who paid more attention to production date information of food cared more about the safety of their food. So it is intuitive that those participants were more conservative on the acceptance of GM crops. Obviously, participants who had more trust in the food industry believe the industry only allows the production of GM crops if the crops are safe so they would have higher acceptance of GM technology.

(3)We found that the knowledge and cognition level of GM agricultural products does significantly impact the acceptance of GM crops. After adding interaction term *cog*label* cognitive level has a significantly positive impact on the acceptance of GM agricultural products and the coefficient increases significantly. The coefficient of the interaction is positive, indicating that among participants who think GM agricultural products should be labeled, those who are more knowledgeable about GM agricultural products are more likely to accept GM technology.

(4) There is a negative relationship between the degree of risk amplification (*ra*) and the acceptance of GM crops. The psychological amplification of the risk for GM crops would significantly reduce the possibility of accepting GM crops. After adding interaction term between risk amplification and trust in the food industry in model 2 (*ra*trust*), the coefficient is doubled and becomes very significant. This shows that when the trust in the food industry is high, it is very likely to alleviate the inhibitory effect of risk amplification on producers' GM crop acceptance.[3]

[3]5% of the subjects made it clear that many agricultural products in life are genetically modified, and there are no major safety problems.

4.1.2 Demographic variable coefficients

Among the demographic variables, only age and education significantly affected the acceptance of transgenic technology. Older participants are less likely to accept GM crops than younger ones. On one hand, the education level of the older generation in China's rural areas is relatively low; On the other hand, older participants' witnesses of the hard times before the Chinese economic reform and open-up make them very cautious about adopting new things with uncertainty. Therefore, their possibility of accepting GM crops is low. As expected, participants with higher education level are more likely to accept GM crops.

4.2 Marginal effect regression

In the above regression, the estimated coefficient reflects the influence of the variable on the explained variable. Overall, the marginal effect test is consistent with the previous benchmark regression results, and further explains the results. The marginal effect test results are as follows (Limited by space, only significant and influential variables are displayed):

First, the three core explanatory variables: risk amplification, risk perception and relative risk coefficient, which have passed the significance test under the five acceptance dimensions. The probability of acceptance decreases with each increase of one unit. "General acceptance" is the peak, which is 4.8%, 2.3%, 1.6% respectively. The very unacceptable probability increased by 10.8%, 5.2% and 3.7% respectively. Similarly, the decision-making made by the three in the degree of non-acceptance and very acceptance does not show too high probability. other variables that have a significant impact: The person in charge of purchasing food in the family is 6.7% higher than the non-person-in-charge, and the probability of general acceptance is 3%; For each unit of cognitive level of GM food, the degree of very non acceptance of GM crops is 4.5%, and the probability of general acceptance is 2%; For each grade of negative attitude towards GM food, the probability of very non acceptance increases by 13.7%, and the probability of general acceptance is 6.1%; It is considered that the subjects who should be labeled have a 20.3% higher probability of not accepting transgene than the opponents, and a 9% lower probability of generally accepting transgene, which has a great impact. The interaction items between the degree of risk amplification and the degree of trust in the country, the cognition of GM food and whether it should be labeled decreased by 3.2% and 4.9% respectively.

Table 1. Estimation results using ordered logit model

variable	Model 1	Model 2
ra	-0.249***(0.088)	-0.691***（0.214）
rp	-0.488**（0.169）	-0.471***（0.170）
rr	-0.300**（0.104）	-0.307***（0.112）
gender	0.26（0.230）	0.295（0.231）
age	-0.022*（0.012）	-0.020*（0.012）
marry	-0.297（0.279）	-0.243（0.275）
nm	0.049（0.102）	0.049（0.102）
under7	-0.049（0.257）	-0.075（0.257）
beyond60	-0.203（0.226）	-0.201（0.226）
edu	0.366***（0.119）	0.363***（0.119）
mhi	0.007（0.059）	0.004（0.059）
char	-0.387（0.242）	-0.409*（0.244）
freq	0.132*（0.082）	0.137*（0.082）
trust[4]	0.063（0.151）	
cog	-0.029（-0.090）	
atti	-0.097**（0.183）	-0.988***（0.184）
knowl	-0.254**（0.112）	-0.266**（0.112）
label	-0.815**（0.304）	-0.992***（0.373）
*ra*trust*		0.178**（0.077）
*cog*label*		0.063（0.095）

Note: Significance indicated by (10%)*, (5%)**, and(10%)***. Standard errors are in parentheses

5. Summary and discussion

In this paper, using producer samples from three Chinese provinces, we estimated participants' relative risk preference coefficient through gambling experiments, and explored participants' risk amplification degree and risk perception of GM crops. We had several findings: First, in the context of risk, higher levels of knowledge and cognition does not necessarily make a producer more rational. Risk perception and attitude significantly affect how producers make decisions and play a key role in their risk management and decision-making. Second, labeling GM agricultural products helps producers with high cognitive level reduce psychological uncertainty and improve their acceptance of GM agricultural products. Third, a higher level of trust in a country's food industry can help prevent the non-adoption-behavior caused by the excessive risk amplification of transgenic technology.

Based on the results, we make the following recommendations to improve producers' adoption of new technologies such as GM crops. First, a supportive production environment and consumer market will reduce producers' risk aversion and producers can adopt new technologies with less hesitation. Government should improve agricultural insurance, improve risk dispersion mechanisms, and provide sufficient financial support to

[4] After adding the interaction terms, *cog* is significant, but *trust* is no longer significant, so the regression coefficient of *trust* is not reported.

ensure that producers will not suffer large losses due to the adoption of new technologies. Second, government or organizations can conduct trainings to educate producers about new technologies to help them establish accurate risk perceptions and improve their risk management strategies and set up effective risk avoidance mechanisms. Third, the government should be open and transparent in the efficacy, advantages and disadvantages of new technologies. Only by eliminating producer concerns and improving their trust in the food industry can we minimize the risk amplification of GM technology. Fourth, the government should develop policies to attract young talents to build villages, improve the income of producers relying on new agricultural technologies and value-added agriculture, and make young people more receptive to emergent technologies, which is also conducive to the adoption of new technologies.

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References

1. Bernstein J. A., L. I. Bernstein and L. Bucchini. 2003. Clinical and laboratory investigation of allergy to genetically modified foods. Environmental Health Perspectives 111 (8), 1114-1121. https:// doi.org /10.1289/ehp.5811.
2. Brick K. and M. Visser, 2015. Risk preferences, technology adoption and insurance uptake: A framed experiment. Journal of Economic Behavior and Organization 118, 383-396. https: //doi.org /10.1016 /j.jebo.2015.02.010.
3. Liu, E. M. 2013. Time to change what to sow: Risk preferences and technology adoption decisions of cotton farmers in China. Review of Economics and Statistics 95(4), 1386-1403. https://doi.org/ 10.1162/REST_A_00295.
4. Hancock J. F. 2003. Frame work for assessing the risk of transgenic crops. Bioscience. 53 (5), 512-519.https://doi.org/10.1641/0006-3568(2003)053[0512:AFFATR]2.0.CO;2.
5. Huang, J., R. Hu, S. Rozelle, F. Qiao and C.E. Pray. 2002. Small Holders, Transgenic Varieties and Production Efficiency: The Case of Cotton Farmers in China. Australian Journal of Agricultural and Resource Economics 46 (3), 1-21. https://doi.org/10.1079/ 9780851 9961 89. 0393.
6. Kasperson R. E., O. Renn and P. Slovic. 1988. The social amplification of risk: A conceptual framework. Risk Analysis 8(2), 178-187. https: //doi.org/10.1111/j.1539-6924.1988. tb01168.x.
7. Lee,S., N.Lee, and C.E Dockter. 2020. Effects of Message Presentation Type on GM Food Risk Perception, Similarly Judgment, and Attitude. Health Communication 6(9), 1-11. https: // doi. org /10.1080/10410236.2020.1787926.
8. Lusk J. L and K. H. Coble. 2005. Risk perceptions, Risk preference, and Acceptance of risky food. Journal of Agricultural Economics 87(2), 393-405. https://doi.org/10.1111/j.1467-8276.2005.00730.x.
9. McCloskey, D. N. and A. Carden. 2020. Leave Me Alone and I'll Make You Rich. In Leave Me Alone and I'll Make You Rich. University of Chicago Press. https://doi.org/10.1111/ECAF.12491.
10. Umezawa T, M. Fujita and Y. Fujita Y. 2006. Engineering Drought Tolerance in Plants: Discovering and Tailoring Genes to Unlock the Future. Current Opinion in Biotechnology 17(2), 113-122. https://doi.org/10.1016/j.copbio.2006.02.002.
11. Zhao, L., H. Gu, C. Yue and D. Ahlstrom. 2013. Consumer welfare and GM food labeling: A simulation using an adjusted Kumaraswamy distribution. Food Policy 42, 58-70. https://doi.org /10.1016/j.foodpol.2013.06.006.