AgBioForum, 20(1): 46-53. ©2017 AgBioForum.

Health-risk Concerns vs. Medical Benefits of the GM Technology

Yoko Saito
Hokkaido University, Japan

Yuki Sasakawa
Life & Bio Plaza 21, Japan

Yutaka Tabei
Institute of Agrobiological Sciences (NIAS), National Agriculture and Food Research Organization (NARO), Japan

Shoichi Ito
Kyusyu University, Japan

Genetically modified crops have been controversial from a health—as well as an environmental—standpoint, and the science community puts substantial effort into communicating with consumers. Relevant to the communication effort, GM technology is now being used to expand food as well as agricultural functionalities, offering the possibility of wider consumer acceptance. A case in point is the development of a GM rice that alleviates allergic reactions to cedar pollen. We conducted an online consumer survey of those manifesting an allergic reaction and investigated whether they respond positively to the new GM benefit. Our results indicate that respondents who perceive at least the possibility of a consumer functionality in GM technology tend to have little health-risk concern in general, and tend to be willing to try medical rice in particular. The implication is that GM acceptability can be influenced by the presence of a positive functionality and not by just the apparent absence of negative ones.

Key words: consumer risk perceptions, willingness-to-try, genetically modified rice, immunotherapy treatment, GM medical benefits.

Introduction

The diffusion of genetically modified (GM) crops depends crucially on whether consumers are adequately motivated to buy them. Most commercialized GM crops developed so far have been modified in agronomically important traits—namely, herbicide tolerance and insect resistance—that benefit production in some manner. Farmers may receive economic benefits from these production characteristics. However, consumers in developed countries such as the European Union, Japan, and, to a lesser extent, the United States do not generally see any positive benefits in consuming GM products. Rather, they are concerned about the risks to their health and the environment (Costa-Font, Gil, & Traill, 2008; Sasakawa, Ishikawa, & Tabei, 2011). Multi-country consumer surveys indicate Japanese consumers have a more conservative attitude toward GM foods than US or Taiwanese students do, supportive of the mandatory labeling (Chern, Rickertsen, Tsuboi, & Fu, 2002). More specifically, McCluskey, Grimsrud, Ouchi, and Wahl (2003) concluded that the Japanese market for GM crops is unpromising because consumers perceive a substantial risk in GM foods. The demand for GM technology, in short, represents a controversy between GM consumers and producers.

Adding new functionalities to GM products can influence this debate by providing additional value for particular types of consumers (Deodhar, Ganesh, & Chern, 2008; De Steur et al., 2010). Golden rice, for instance, can provide vitamin A to expectant mothers, supply micronutrients to malnourished children, and contribute to alleviating hidden hunger in developing economies (Hefferon, 2015). In addition to this nutritional functionality, pharmaceutical or plant molecular farming—generally called biopharming—has recently surged and now offers new prospects for the future (Sabalza, Christou, & Capell, 2014; Stoger, Fischer, Moloney, & Ma, 2014). In spite of the emerging applications of agricultural GM technology to pharmaceutical purposes, public perceptions and patient acceptance have been little studied, and in particular much less than have agricultural applications.

The "benefit-acceptance hypothesis" is concerned with whether consumers change their perceptions of GM products if they learn they bring such direct benefits as increased shelf life or nutritional functionality (Lusk, Moore, House, & Morrow, 2004). Loureiro and Bugee (2005) showed that appealing to a personal benefit such as an enhanced flavor or nutritional value can help attract consumers to the idea of genetic modification. Introduction of such second-generation GM products, namely those with direct appeal to consumers, is increasingly expected to improve public acceptance of GM technology. Gaskell (2000) shows the consumer acceptance rate depends on the purpose of the GM application; a medical purpose brings the highest acceptance rate of all applications. Burton and Pearse (2002) compared the willingness to pay (WTP) of two genera-

tions of GM foods. Their results indicated that the cost-reduction aspect of first-generation GM foods led consumers to expect price reductions, while the medicinal benefits of second-generation GM crops led them to expect price premiums. Einsiedel and Medlock (2005) employ a "purpose test" in their focus group interview and find that benefits can vary depending on application purpose, holding the risks of the various applications constant. Edible vaccines had the highest acceptance rate of the GM purposes examined. These studies suggest GM crops' medical benefits tend to be more desirable than are their other functionalities. Taking this thinking further, we examine here whether those perceiving at least the possibility of a consumer functionality in GM technology are more likely to be accepting of GM medical benefits in particular.

Medical Rice Technology

In Japan, Takaiwa (2004) has used gene recombinant technology to develop a new rice variety to control cedar pollen allergy. It is expected to mitigate allergic reactions by influencing the patient's immune system. According to Baba and Nakae (2008), 30% of the Japanese population displays allergic reactions to cedar pollen. Generally, there are two ways to control allergic reactions—symptomatic treatment and definitive treatment. In symptomatic treatment, patients buy a drug without medical prescription. These drugs are only temporarily effective. Definitive treatment on the other hand intends a complete cure, and immunotherapy is currently the only way of doing so. Immunotherapy alleviates the allergic reaction by way of gradual ingestion of the diluted allergen.

Injection immunotherapy is the only presently available definitive treatment. However, it requires patients to visit hospitals regularly. Immunization by regular intake of medical rice, still in its development stage, also appears to be an effective definitive treatment. As visualized at its current research stage, medical rice would be delivered to patients by mail in a single package, its volume depending on the medical prescription. Patients are instructed to eat one pack per day for six months, saving patients the considerable time and cost of hospital visits to receive injections.

Recombinant technologies similar to medical rice are expected to be applicable to other infectious diseases. Their success will depend on whether patients are willing to accept the associated dietary treatments. The question we address in the present study is whether awareness of the benefits of consuming medical rice can sufficiently motivate patients suffering from cedar pollen allergy to purchase it. Because the rice is now only at the clinical stage, we must focus on the factors helping to predict its long-run acceptability. Such factors include those influencing the consumer's willingness to try this rice in particular and tendency to regard GM products as carrying a health risk in general.

> GM rice for cedar pollen allergy is in the development process by the National Institute of Agrobiological Sciences (NIAS), and is planted in experimental fields used exclusively for genetically modified rice. The effectiveness of this rice is investigated in laboratory animals by immunotherapy specialists. Since this rice is defined as "medicine," it is provided to the patients under the guidance of a medical doctor and prescription. Patients are instructed to use one bowl, i.e., about 150g of cooked medical rice once a day for six months.

Figure 1. Description of medical rice provided to survey respondents.

Data Collection and Respondent Profile

Medical rice for cedar pollen allergy is still in the development stage at Japan's National Institute of Agrobiological Sciences. Following the Cartagena Protocol on Biosafety, it is subjected to field trials to investigate its environmental impacts. Our survey data were enumerated through web research firm MACROMILL in December 2013, a description of which is provided in Figure 1. Previously registered anonymous respondents were screened on the basis of whether they revealed an allergy to cedar pollen and were willing to answer the "Survey on Cedar Pollen Allergy" questions. At the start of the survey, they were not informed that the survey would include questions relating to GM technology or GM rice. This helped limit any selection for, and consequent bias resulting from, respondent attitude toward GM technology or foods.

The total number of respondents was 412, all of whom had chronic allergic reactions to cedar pollen. Table 1 shows the age and gender distribution of these respondents. The majority were female, as is often the case with studies of consumer evaluations of food products (Saito, Saito, & Sembokuya, 2009). Respondent allergy status is shown in Table 2. More than 70% of the respondents report that the allergy has a negative effect on their quality of life (*Difficulty*). However, only half have consulted a medical doctor or undergone an allergy test. Most have not visited hospitals, although many feel some kind of inconvenience in their daily life. For those who do, we define a "medical benefit" as the respondent's overall support for exploiting GM technology to

Table 1. Summary of respondent age and gender.

	Years	%
Age	20–29	14.6
	30–39	31.3
	40–49	24.3
	50–59	19.9
	60–69	8.3
	70–79	1.7
Gender	Male	41.0
	Female	60.0

Table 2. Allergy status of sample respondents.

	No	Yes
Does your allergic reaction reduce your quality of life? (*Difficulty*)	123 (29.9)	**289 (70.2)**
Have you consulted a medical doctor for your allergy?	**224 (54.4)**	188 (45.6)
Have you checked your allergic status with a patch test or blood examination?	**201 (48.8)**	211 (51.2)

Note: Parentheses indicate shares.

add medical functionalities (providing definitive cures) to agricultural products. Consequently, appealing to such an attitude is a key to persuading sufferers to accept medical rice.

Framework for Predicting Medical Rice Acceptance

Trade-off

Given the concern over agricultural applications of GM technology, consumer acceptance of GM crops remains low. Medical applications of GM methods, however, may influence consumer receptivity, especially once a direct medical benefit has been shown. To help predict receptivity, it is useful to think in terms of two opinion variables that in several respects are in polar opposition to one another—human health risk (*HuRisk*) and willingness-to-try (*WTT*). *HuRisk* represents the consumer's concern over GM crop technology *in general*, while *WTT* indicates willingness to try the GM medical rice *in particular* (Table 3). These two indicators allow the consumer to be in a quandary—to be either generally supportive of GM methods but specifically opposed to the present allergy rice application or vice versa—or to have a mutually reinforcing opinion on both.

Because medical rice is still in the trial stage, we cannot yet examine the factors influencing its actual diffusion. However, we can get an indirect evidence of its future diffusion by assessing the influences on the consumer attitudes that themselves likely affect future consumption. To best examine the possibility of long-run acceptance of medical rice, we would follow Gaskell (2000) and need to increase the number of consumers who are unconcerned about the human health risks *and* willing to try this medical rice (the best solution), specifically the "No *HuRisk* / Yes *WTT*" combination in Table 3. As what we will call the second-best solution, we would increase the number of consumers who have great health-risk concerns with GM technology but a high willingness to try medical rice—*or* low willingness to try the rice but low health-risk concerns with GM technology, the "Yes *HuRisk* / Yes *WTT*" or "No *HuRisk* / No *WTT*" combination. The tendency to accept the rice as a permanent allergy treatment clearly would improve as the consumer moves from either of the second-best categories toward the best category. The relevant question in our framework then is to identify the factors bringing consumers in that direction.

Table 3. Predicting medical rice acceptance.

		Willingness-to-try (*WTT*)	
		Yes	**No**
Human health risk (*HuRisk*)	Yes	2nd best	3rd best
	No	Best	2nd best

Human Health Risk and Willingness to Try

We classify respondents into four groups based on their human health-risk concerns with GM crops (*HuRisk*) and their willingness-to-try medical rice (*WTT*). These variables are respectively measured by way of the following five-point (1-5) Likert-scale questions, where strongly agree is 5 and strongly disagree is 1.

> (*i*) Health-risk concerns of GM crops (*HuRisk*): Do you think GM crops pose potential risks to human health?
>
> (*ii*) Willingness-to-try medical rice (*WTT*): Are you willing to try medical rice despite that it is only at the clinical stage?

Most previous studies aiming to identify factors effective in mitigating consumers' health-related concerns with *conventional GM crops* ask the first type of question (Question *i*) only. However, respondents suffering from a severe allergic reaction to cedar pollen may try medical rice if they think it may be successful in

Table 4. *HuRisk* and *WTT*: Strength of respondent agreement or disagreement.

	Variable name	Strongly agree 5	Agree 4	Neither agree nor disagree 3	Disagree 2	Strongly disagree 1
GM crops pose potential risks to human health (*i*)	*HuRisk*	29	159	172	42	10
		7.0	38.6	41.8	10.2	2.4
I would like to try medical rice even at the clinical trial stage (*ii*)	*WTT*	15	42	116	163	76
		3.6	10.2	28.2	39.6	18.5

Table 5. Trade-off between *HuRisk* and *WTT*.

		WTT		
		Yes	**No**	**Total**
HuRisk	Yes	28 (6.8)	160 (38.8)	188 (45.6)
	No	29 (7.0)	195 (47.3)	224 (54.4)
Total		57 (13.8)	355 (86.2)	412 (100)

Note: Parentheses indicate shares.

reducing their allergic reactions and even if—especially since this rice is only at the clinical stage—they think GM food products are generally risky (Question *ii*). *WTT* represents willingness to participate in a medical rice *trial*. But that is only one of the factors affecting an individual's long-run adoption. Table 4 provides the sample data of the answers to these two questions. Almost half of the respondents (45.6%) expressed concern about a general health risk in GM technology (*HuRisk*) by indicating "strongly agree" or "agree" to the first question, while 13.8% agreed or strongly agreed that they would try medical rice. Most respondents were concerned about the human health risks of GM technology and a few expressed interest in medical rice. Moreover, 58.1% of respondents answered "disagree" or "strongly disagree" to the *WTT* question, revealing strong resistance to this new GM technology.

Table 5 shows the cross tabulations of the responses to these two questions. For each, respondents who answered "strongly agree" or "agree" are categorized as "yes" and the remainder as "no." About 46% of the respondents (188 persons) considered that GM crops pose risks to human health. About 14% (57 persons) were willing to try medical rice (best). Among the 57, about half (29 persons) do not consider GM crops to pose health risks. The remaining half face a trade-off (second best): they are willing to try medical rice in particular but have strong health-related concerns about GM crops in general. Finally, about half the respondents (195 persons) are unwilling to try medical rice but do not think GM technology brings a risk to human health.

Estimation Model

Consider two indicator variables, WTT_i and $HuRisk_i$, respectively taking the value 1 if the i^{th} respondent is willing to accept medical rice and value 0 if (s)he thinks GM crops pose health risks (Table 5):

$$WTT_i = \begin{cases} 1 & if \quad W_i^* \geq 0 \\ 0 & otherwise \end{cases}, \tag{1}$$

$$HuRisk_i = \begin{cases} 1 & if \quad R_i^* \geq 0 \\ 0 & otherwise \end{cases}, \tag{2}$$

where W_i^* and R_i^* are latent variables respectively reflecting a willingness to try medical rice and a subjective evaluation of the human health risks of GM crops. The objective of this analysis is to identify the factors affecting these two latent variable and determine how those factors affect the consumer's position in the Table 3 matrix. Each latent variable—evaluated in terms of the respondent characteristics—is specified in linear form:

$$\begin{aligned} W_i^* = {} & \beta_0^W + \beta_1^W \ln Benefit_i + \beta_2^W \ln EnvRisk_i \\ & + \beta_3^W \ln ConsGM_i + \beta_4^W \ln GMKnow_i \\ & + \beta_5^W immKnow_i + \beta_6^W Difficulty_i + \beta_7^W Severity_i \\ & + \beta_8^W Gender_i + \beta_9^W Age_i + \varepsilon_i^W, \end{aligned} \tag{3}$$

$$\begin{aligned} R_i^* = {} & \beta_0^R + \beta_1^R \ln Benefit_i + \beta_2^R \ln EnvRisk_i \\ & + \beta_3^R \ln ConsGM_i + \beta_4^R \ln GMKnow_i \\ & + \beta_5^R immKnow_i + \beta_6^R Difficulty_i + \beta_7^R Severity_i \\ & + \beta_8^R Gender_i + \beta_9^R Age_i + \varepsilon_i^R. \end{aligned} \tag{4}$$

In these equations, *Benefit*, *EnvRisk*, and *ConsGM* respectively measure (a) the extent (1=strongly disagree; 5=strongly agree) to which a respondent supports the use of GM technology to develop fuller functionalities in agricultural products; (b) the belief that GM crop production poses environmental risks; and (c), a conser-

Table 6. Distributions of responses to questions posed.

Variable		Question number	Strongly agree 5	Agree 4	Neither agree nor disagree 3	Disagree 2	Strongly disagree 1
Benefit	I would like to try functional agricultural products developed with GM technology.	Q_B1	5	37	195	132	43
			1.2	9.0	47.3	32.0	10.4
	It is beneficial to develop functional agricultural products by using GM technology.	Q_B2	7	57	215	94	39
			1.7	13.8	52.2	22.8	9.5
EnvRisk	GM crops lead to genetic pollution or introgression.	Q_E1	35	174	165	30	8
			8.5	42.2	40.1	7.3	1.9
	GM crop production has negative effects on the natural environment.	Q_E2	37	171	155	41	8
			9.0	41.5	37.6	10.0	1.9
ConsGM	GM crop development is unnecessary.	Q_C1	43	92	197	65	15
			10.4	22.3	47.8	15.8	3.6
	I do not want to try medical rice because it is developed with GM technology.	Q_C2	33	83	182	87	27
			8.0	20.2	44.2	21.1	6.6
Variable		**Question number**	**Know very well** **5**	**Know well** **4**	**Know partly** **3**	**Have heard** **2**	**Do not know at all** **1**
GMKnow	Most consumers ingest GM crops through cooking oil.	Q_G1	15	59	82	96	160
			3.6	14.3	19.9	23.3	38.8
	Sixty percent of the cooking oil processed in Japan is made from GM crops.	Q_G2	11	30	59	79	233
			2.7	7.3	14.3	19.2	56.6
	Japan imports GM crops by way of animal feeds.	Q_G3	18	48	55	102	189
			4.4	11.7	13.4	24.8	45.9
	Ninety percent of crops produced in major crop-exporting countries such as the United States and Brazil are GM crops.	Q_G4	15	42	42	77	236
			3.6	10.2	10.2	18.7	57.3
immKnow	To what extent are you familiar with the immunotherapy?	Q_I	11	27	67	124	287
			2.1	5.2	13.0	24.0	55.6
Variable		**Question number**	**Very severe** **5**	**4**	**3**	**2**	**Not severe** **1**
Severity	How severe is your allergy reaction?	Q_S	17	90	179	93	33
			4.1	21.8	43.5	22.6	8.0

vative attitude toward the use of GM technology to develop new crop varieties, including medical rice (Table 6). These three variables each consist respectively of two questions, the sample point for a given individual *i* obtained by averaging the answers to the two questions (Table 7). *Benefit* is expected to positively affect the tendency to try medical rice while alleviating the consumer's perception of a risk to human health (*HuRisk*). Respondents concerned about an environmental risk in GM technology naturally might be concerned about a health risk as well, so *EnvRisk* would boost *HuRisk*. For the same reason of a general attitude, *ConsGM* would push *WTT* down and *HuRisk* up.

GMKnow indicates the extent (1=do not know at all; 5=know very well) to which a respondent is aware that GM crops are commonly used in food products. This variable is composed of four questions, and the observed sample point for individual *i* is obtained as the average of the responses to these four questions. We expect that a greater understanding of GM use in the

Table 7. Definition and descriptive statistics.

Variable	Definition	Mean	St. dev.	Min	Max
Benefit	(Q_B1 + Q_B2)/2	2.670	0.79	1	5
EnvRisk	(Q_E1 + Q_E2)/2	3.468	0.80	1	5
ConsGM	(Q_C1 + Q_C2)/2	3.110	0.81	1	5
GMKkow	(Q_G1 + Q_G2 + Q_G3 + Q_G2)/4	1.973	1.04	1	5
immKnow	Q_I: 1 if "know very well" or "know well;" 0 otherwise	0.080	0.27	0	1
Difficulty	Dummy variable: 1 if quality of life is negatively affected	0.701	0.46	0	1
Severity	Subjective severity: 1 if "not severe;" 5 if "very severe"	2.915	0.96	1	5
Gender	Male=1; Female=0	0.410	0.49	0	1
Age	Continuous variable	42.43	12.1	20	76

Note: See question number in definition in Table 6.

food industry provides a familiarity with the technology and thus boosts the tendency to try medical rice. *immKnow* is a dummy variable taking the value 1 if the respondent "knows very well" or "knows well" about immunotherapy treatment. Our hypothesis is that familiarity with this kind of treatment is also conducive to trying medical rice. *Severity* indicates the extent (1=not severe, 5=very severe) to which a respondent sees his/her allergy as serious, suggesting a greater inclination to try medical rice.

Tables 6 and 7 provide the descriptive statistics and information about the probability distributions of these variables. About 10% of the respondents agree or strongly agree with the use of GM technology in the development of food-functional agricultural products (*Benefit*), and about half indicate concern with the environmental risks of these products (*EnvRisk*). About 30% display a conservative attitude (agree or strongly agree with the "concern" statements) toward the use of GM breeding technology (*ConsGM*). Responses to the *GMKnow* questions suggest general knowledge about GM use in the Japanese food industry is very weak. In answers to the *immKnow* questions, about 55% indicate they are not even aware of immunotherapy.

In sum, Equations 1 to 4 together characterize the respondent's attitude toward medical rice. *HuRisk* and *WTT* might be correlated with one another. Disturbances ε_i^W and ε_i^R in Equations 3 and 4 are assumed therefore to follow a bivariate normal distribution with mean 0, variance 1, and correlation ρ. Equations 1 to 4 are estimated with bivariate probit techniques (Hill, Griffiths, & Lim, 2012).

Estimation Results

Estimates of bivariate probit models 1 to 4 are presented in Table 8.[1] The result is simplified in Figure 2 by expanding Table 3 and 5 so as to show at a glance each factor's direction-of-effect on respondent attitude. As indicated above, No *HuRisk* / Yes *WTT* (the third quadrant in Figure 2), is the situation most conducive to the diffusion of the technology. Yes *HuRisk* / Yes *WTT* and No *HuRisk* / No *WTT* combinations are the second-most conducive. It is important for diffusion therefore to determine the factors affecting movement toward or away from these two possibilities.

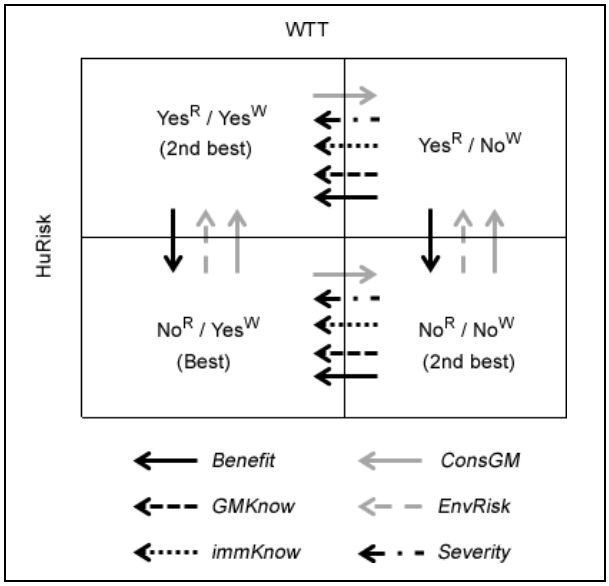

Figure 2. Affecting factors to HuRisk and WTT.

1. *Correlation (ρ) between disturbances ε_i^W and ε_i^R is positive but insignificant. Thus, we also individually estimate Equations 1-3 and 2-4 with a univariate probit model. The results are quantitatively and qualitatively the same as those presented in Table 8.*

Table 8. Factors affecting health-risk concerns with GM crops and willingness to try medical rice.

		HuRisk concerns with GM crops			*WTT* medical rice		
Variables	**Arrows in Figure 2**	**Coefficient**	**Std. error**		**Coefficient**	**Std. error**	
ln *Benefit*	←	-0.536	0.236	**	0.509	0.282	*
ln *EnvRisk*	← – –	3.498	0.438	***	0.526	0.388	
ln *ConsGM*	←	1.239	0.358	***	-0.712	0.351	**
ln *GMKnow*	← – – –	-0.037	0.165		0.398	0.187	**
immKnow	← ·····	0.159	0.280		0.636	0.274	**
Difficulty		0.113	0.172		0.219	0.220	
Severity	← · –	0.044	0.083		0.316	0.097	***
Gender		-0.188	0.162		0.197	0.189	
Age		-0.009	0.007		0.012	0.008	
Con.		-5.081	0.751	***	-3.562	0.743	***
ρ				0.175 (0.130)			
Log-likelihood				-331.247			
Observations				412			

Note: Parameters are estimated with bivariate probit.

, **, * Statistical significance at 10%, 5%, and 1% levels, respectively*

The *Benefit* variable significantly and negatively affects *HuRisk* and positively affects *WTT*. That is, the more generally favorable one is toward adding food functionality by way of GM technology, the less will one will think GM crops carry a health risk (*HuRisk*) and the more willing one will be to try out medical rice in particular. In brief, the more broadly favorable the consumer is to the technology, the more likely (s)he is to fall into medical rice's No *HuRisk* / Yes *WTT* group (solid arrows in Figure 2), where the health-risk effect and willingness-to-try effect positively reinforce one another. Successful diffusion of a functionality-added GM crop is significantly enhanced if the consumer is aware of the GM technology's direct benefits in crop breeding and development. Our benefit-acceptance hypothesis is, in that respect, confirmed.

On the other hand, an unfavorable or conservative attitude toward GM technology (*ConsGM*) significantly lifts *HuRisk* and impairs *WTT*. That is, the more conservative the attitude toward GM technology itself, the greater health-risk concern over GM foods and the lower willingness to try medical rice as a way of alleviating allergy symptoms. In both these respects, an unfavorable attitude toward GM technology leads respondents away from the No *HuRisk* / Yes *WTT* combination, discouraging technology diffusion (gray solid arrows in Figure 2). The net effects of *Benefit* and *ConsGM* on *HuRisk* and *WTT* therefore are in exact opposition to one another.

EnvRisk, *GMKnow*, and *immKnow*, on the other hand, significantly affect only one of the latent variables *HuRisk* or *WTT*. Respondents who believe GM crop production poses environmental risk (*EnvRisk*) tend to have *HuRisk* concerns with GM technology also (gray dashed line in Figure 2), but their willingness to try medical rice is not significantly affected. A general understanding of the GM (*GMKnow*) food industry is significantly conducive to trying out medical rice (black dashed line in Figure 2) but has no effect at all on general health-risk concerns. Both these factors therefore will tend—although in only one rather than two ways—to improve long-run medical rice adoption.

Finally, the more that consumers understand about immunotherapy treatment (*immKnow*), and the more severe their allergy problem is (*Severity*), the greater is their willingness to try the medical rice (dotted line for *immKnow* and dot-dashed line for *Severity* in Figure 2). Understanding immunotherapy tends to ease the consumer's worry about it, and cedar pollen allergy severity provides a direct inducement to seek it out. Consequently, their positive effects on WTT and nonsignificant effects on GM crop health-risk concerns are equally unsurprising. Each moves the consumer toward the 'second-best' combination, Yes *HuRisk* / Yes *WTT*.

Conclusions

First-generation GM crops benefited farmers directly but appealed to consumers only by way of their indirect

effects on product prices. The willingness to consume GM foods therefore has been heavily influenced by the presence or absence of health-risk concerns. Second-generation technology, in contrast, is adding new functionalities to GM products that benefit consumers directly. The object of this study has been to examine how consumer attitudes toward food-functional GM products are formed. In particular, we assess the chain of relationships between more generalized attitudes toward GM technology and the more specific attitudes governing the acceptability and diffusion of a GM rice variety that controls an allergy to cedar pollen.

Because this new medical rice variety is still undergoing trials, we cannot yet observe the diffusion of this new rice among consumers and allergy patients. Instead, we examine how generalized attitudes to and knowledge about GM technology, and the severity of the allergy, affect a consumer's health-risk concerns over GM foods and willingness to trial-consume the new rice. Factor effects on these latter two attitudes, constructed as latent variables, are then used to impute factor effects on the likelihood of that the medical rice will be adopted on a long-run basis.

We find, for medical rice, that boosting the perceived possibility of a direct consumer benefit in a GM product would reduce the concern about the product's riskiness and enhance the willingness to consume it on a trial basis, in each case lifting the likelihood of long-run adoption. Any reduction in the conservativeness of attitude toward GM technology would have the same, mutually reinforcing effect on demand. The other factors we examined—knowledge about the GM food industry and about immunotherapy, worries about GM's environmental risks, and the severity of the allergy suffered—each has unambiguous implications for long-run adoption, although only by way of either one of the two latent variables.

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