Determinants of Willingness to Pay for Non-Genetically Modified Foods: The Mediating Role of Risk Perception

Taku Terawaki*, Naoya Kaneko†, and Wen S. Chern†

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*Taku Terawaki is associate professor at the College of Economics, Ritsumeikan University, 1-1-1 Noji-Higashi, Kusatsu, Shiga, 525-8577, Japan. Phone/Fax: +81-77-561-4974. E-mail: ttt20009@ec.ritsumei.ac.jp

†Naoya Kaneko and Wen S. Chern are, respectively, graduate research associate and professor, Department of Agricultural, Environmental, and Development Economics, The Ohio State University.

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Abstract

This study examines the mediating role of the risk perception of genetically modified (GM) foods in the relationship between personal characteristics and the willingness to pay (WTP) a premium for non-GM soybean oil. The data were collected through contingent valuation surveys conducted in the United States and Japan. Our empirical results in both countries show that: (1) consumers' risk perception plays an important role as a mediator between the personal characteristics and the WTP, and (2) objective knowledge of GM foods has a negative impact on the WTP, via its link to the risk perception.

Keywords: Genetically Modified, Contingent Valuation, Willingness to Pay, Risk Perception, Mediation

JEL Classification: D12, C35

Introduction

The recent increase in the worldwide production of genetically modified (GM) crops has been causing great public concern about the safety of the foods that are produced using GM crops. Consumers are strongly opposed to the GM foods in those countries that import main GM crops (i.e., GM soybeans and corn). Moon and Balasubramanian (2004) show that U.K. consumers have less favorable attitudes toward GM foods than U.S. consumers while Lusk et al. (2004) show that French consumers are not only less accepting of GM foods than U.S. consumers but also unwilling to accept GM foods at all even if they are provided with positive information regarding GM foods. The EU countries, including the U.K. and France, are important export destinations of the U.S.-produced GM crops. In order to devise a comprehensive strategy regarding GM crop production and exports, it is important for U.S. agricultural producers, biotechnology industries, and policy makers to understand what determines the consumer acceptance of GM foods. By understanding how consumers' socio-demographic characteristics affect their acceptance of GM foods, U.S. farmers and exporters will be able to develop a more detailed marketing plan. Furthermore, if the determinants of GM acceptance include controllable factors, the U.S. government and agribusiness firms can hope to affect consumers' attitudes toward GM foods in their favor.

Many economic valuation studies regarding GM foods have investigated the determinants of consumers' willingness to pay (WTP) a premium for non-GM foods, but their results are not particularly encouraging. Baker and Burnham (2001), Li, McCluskey, and Wahl (2004), and Kaneko and Chern (2005) indicate that some cognitive variables affect the WTP, but virtually all socio-demographic variables have no impact on the WTP.[1] Since cognitive variables are usually unavailable without conducting a survey, they are not usable as predictors of the WTP in practice; nor can they be used as policy variables because consumers' subjective perception is hard to control. A fundamental question now faced by the empirical researchers is whether or not socio-demographic variables really affect the WTP. In a series of studies, Moon and Balasubramanian make a significant contribution to the resolution of this issue. They demonstrate that some socio-demographic characteristics have a significant impact on consumers' risk perception, and, therefore, the impact on the WTP of these characteristics is masked by that of the risk perception (Moon and Balasubramanian 2003). Moreover, they demonstrate that socio-demographic factors play an important role in shaping consumer attitudes toward agrobiotechnology via their link to risk perception (Moon and Balasubramanian 2004). The conceptual framework that Moon and Balasubramanian employ is often called the mediation model in the field of psychology (MacKinnon 2002).

In this study, we use this mediation model to illustrate the role of risk perception as a mediator between the WTP and consumers' socio-demographic variables. For application, we use the data drawn from the contingent valuation survey conducted in the United States and Japan. The Japanese data are used because Japan is one of the most important export markets of U.S.-produced GM crops and because Japanese consumers seem to have higher level of risk perception than U.S. consumers. The purpose of this study is to determine how U.S. and Japanese consumers' WTP a premium for non-GM foods is determined by their socio-demographic and cognitive variables. In so doing, we find which variables directly affect the WTP and which variables exert their influences through the mediator. The paper proceeds with the development of theoretical framework, followed by the description of the contingent valuation survey and data. We then develop the empirical model, present the econometric results, and conclude with the discussion of our findings.

Theoretical Framework

Empirical researchers have studied consumer preferences on GM foods in terms of risks to human health and the environment. Risk perception is undoubtedly one of the most important determinants of consumers' WTP a premium for non-GM foods, but its determinants are not well known. Some consumers are more risk-conscious than others, and we do not know what makes a difference in individual risk perception. It is beyond the scope of this paper to determine the origin of diverse individual perception; we content ourselves with the observation that risk perception depends partly on individual characteristics.

The problem with the use of risk perception as a determinant of the WTP is that risk perception is not purely exogenous in the estimation of WTP. It is affected by personal characteristics as well as the person's innate cognitive ability and orientation, but personal characteristics are routinely used in the empirical literature as determinants of the WTP. If risk perception is used as an explanatory variable together with personal characteristics in the equation for the WTP, we encounter a classic case of multicollinearity. We recognize this problem and invoke the mediation model where risk perception is hypothesized to be a mediating variable.

The mediation model contains three causal paths: (a) the direct path from independent variables to a dependent variable, (b) the path from the independent variables to a mediating variable, and (c) the path from the mediating variable to the dependent variable. Figure 1 depicts these three paths. In our model, personal characteristics correspond to the independent variables, risk perception of GM foods corresponds to the mediating variable, and the WTP a premium for non-GM foods corresponds to the dependent variable. In other words, our model assumes that personal characteristics have an indirect impact on the WTP via their links to risk perception as well as a direct impact on the WTP.

Following Hayes et al. (1995), Lin and Milon (1995), and Lusk et al. (2004), we first define the economic value of GM-free attribute in food products within the framework of state-dependent utility model. In this model, consumers' risk perception of food safety is represented by a Bernoulli distribution with two outcomes: a good state and a bad state of health. An individual is assumed to receive utility $U^g(M, \boldsymbol{x})$ if a good state occurs and to receive utility $U^b(M, \boldsymbol{x})$ if a bad state occurs, where M is money income, $\boldsymbol{x}$ is a vector of personal characteristics, and $U^g > U^b$ for any M and $\boldsymbol{x}$. The individual is also assumed to believe that when he/she eats a non-GM food, the good state occurs with probability 1, and when he/she eats a GM food, the bad state occurs with probability $\pi(\boldsymbol{x})$, which is greater than 0 and less than 1, and the good state occurs with probability $1 - \pi(\boldsymbol{x})$. Then, the individual's expected utility when he/she consumes the GM food is represented as

$$\mathrm{E}\,U = (1 - \pi(\boldsymbol{x}))U^g(M, \boldsymbol{x}) + \pi(\boldsymbol{x})U^b(M, \boldsymbol{x}). \tag{1}$$

Since the (expected) utility when the individual consumes the non-GM foods is $U^g(M, \boldsymbol{x})$, his/her WTP a premium for the non-GM food is represented as

$$U^g(M - WTP, \boldsymbol{x}) = (1 - \pi(\boldsymbol{x}))U^g(M, \boldsymbol{x}) + \pi(\boldsymbol{x})U^b(M, \boldsymbol{x}). \tag{2}$$

This WTP reflects the economic value of GM-free attribute.

Using this equation, we next develop the relationship between the WTP and the individual's jth attribute x_j, under the standard assumption that $\partial U^g/\partial M > 0$. Totally differentiating equation (2) with respect to WTP and x_j yields

$$\begin{aligned} \frac{dWTP}{dx_j} &= \frac{\pi_{x_j}(\boldsymbol{x})(U^g(M, \boldsymbol{x}) - U^b(M, \boldsymbol{x}))}{U^g_M(M - WTP, \boldsymbol{x})} \\ &+ \frac{\pi(\boldsymbol{x})(U^g_{x_j}(M, \boldsymbol{x}) - U^b_{x_j}(M, \boldsymbol{x})) + U^g_{x_j}(M - WTP, \boldsymbol{x}) - U^g_{x_j}(M, \boldsymbol{x})}{U^g_M(M - WTP, \boldsymbol{x})}, \end{aligned} \tag{3}$$

where the subscripts denote partial derivatives with respect to the corresponding variables. The item $\pi_{x_j}(\boldsymbol{x})$ in equation (3) reflects the effect of path (b) in Figure 1, and the $(U^g - U^b)/U_M$ reflects the effect of path (c). And the second term in the right-hand side of equation (3) reflects the effect of path (a) in Figure 1.

Since $U^g > U^b$ and $U_M > 0$, the effect of path (c) is positive. This means that the indirect impact of an attribute on the WTP via their links to risk perception works in the same direction as their direct impact on risk perception (effect of path (b)). That is, if consumers' subjective probability that eating GM foods results in a bad state of health is reduced by an increase in an attribute, the WTP is also reduced at the same time.

On the other hand, the second term in the right-hand side of equation (3) does not provide us with much insight into the direction of the effect of path (a), that is, the direct effect of an attribute on the WTP. However, the first term in its numerator is meaningful. This term indicates that if the utility obtained from a good state increases, while the utility obtained from a bad state decreases, along with an increase in an attribute, the WTP can also increase with the increase in the attribute. For example, people who have a great interest in healthy lifestyle may receive more utility from the good state of health, and may lose more utility from the bad state of health, than the people who do not have an interest in it. If so, the interest in healthy lifestyle will directly affect the WTP in a positive way.

Contingent Valuation Survey and Data

In order to evaluate the GM-free attribute in food products, researchers have used various elicitation formats in their CV surveys. McCluskey et al. (2003), Grimsrud et al. (2004), and Li, McCluskey, and Wahl (2004) ask the respondents if they are willing to accept a discount on a GM food, when compared to its non-GM counterpart, using the double-bounded dichotomous choice format. Moon and Balasubramanian (2004) ask the respondents if they are willing to pay a premium for a box of non-GM cereals, when compared to its GM counterpart, using the dichotomous choice and payment card formats. In these studies, the respondents are implicitly assumed to prefer non-GM foods to GM foods. This assumption, however, may be somewhat restrictive. Some people might rather prefer GM foods, because the GM foods generally require less herbicides or pesticides. In our survey, we gave the respondents an opportunity to express their WTP a premium for GM foods, as well as their WTP a premium for non-GM foods.

In our CV question, respondents are first asked whether they will choose a non-GM or GM food at the current market price. Alternative answers to this question are (1) choose the non-GM food, (2) choose the GM food, (3) consider both equally good (indicate indifference), and (4) consider neither the non-GM nor GM food attractive (choose neither). Answers (3) and (4) may seem to be the same at first glance, but they are definitely different. Choosing neither the non-GM nor GM food does not mean being indifferent between the non-GM and GM foods, but it just means that the utility gain from consuming either of them is less than the utility loss from paying the offered price. If respondents who are indifferent between the non-GM and GM food products, or prefer not to consume either of them are forced to choose one of these two products, they would answer "don't know" or would give no answer. Then, we could not distinguish the "don't know" that comes from indifference from the "don't know" that comes from choosing neither. By including these two options in alternative answers, we hope to pick up the indifferent respondents, who are then included in our sample.

Next, a follow-up question is asked that depends on the answer to the first question. If a respondent chooses the non-GM food in the first question, only the price of the GM food will be discounted in the follow-up question, and then, he/she is asked again whether he/she will choose the non-GM or GM food. Similarly, if a respondent chooses the GM food in the first question, only the price of the non-GM food will be discounted, and then, he/she is asked again whether he/she will choose the non-GM or GM food. The discount rate is chosen at random among five treatments: 5, 10, 20, 30, and 50 percent (Table 1). Those respondents who indicate indifference between the non-GM and GM foods in the first question are randomly offered either a discount on the non-GM food or a discount on the GM food, and then asked whether they will choose the non-GM or GM food. The respondents who indicate indifference again in this follow-up question are excluded from our sample, because this response is judged to be irrational. In the case when a respondent chooses neither the non-GM nor GM food, he/she is asked the reason for it. The respondents who choose neither in the first question are excluded from the sample.

A telephone survey was conducted in the United States, in April 2002. The respondents were drawn from 48 states except Alaska and Hawaii, using the random digit dialing method. A total of 256 respondents completed substantial portions of the questionnaire. On the other hand, a mail survey was conducted in Japan, in February 2003. We recruited a sample of respondents from the metropolitan parts (so-called "23 wards") of Tokyo, using the random digit dialing method, and then mailed them the questionnaire. The effective sample size was 271. In the U.S. survey, the respondents were asked CV questions about the GM attributes of soybean oil, cornflake, and salmon. And in the Japanese survey, soybean oil, tofu (soybean curd), and salmon were chosen as the foods whose GM-free attributes are evaluated. This study focuses on the GM attribute of soybean oil that was included in both surveys because soybean is one of the main U.S. export crops to Japan.

Table 2 shows the definitions of candidate independent variables examined in this study. These variables are classified into three categories: cognitive, habit, and demographic variables. Since cognitive variables are difficult to collect, they will not act as predictors of the WTP in practice; in contrast, habit and demographic variables can serve as predictors of the WTP as they (or their proxies) are easier to obtain. In addition, although O.KNOW and GOVERNMENT are cognitive variables, they can be used as policy variables in the long run. That is, consumer education programs will increase consumers' objective knowledge of biotechnology. Also, improving the government's performance in food safety regulations will increase consumers' assessment of it.

Table 3 shows the descriptive statistics for the mediating variable (risk perception) and all the candidate independent variables in the U.S. and Japanese surveys. A total of 162 respondents in the U.S. survey and 123 respondents in the Japanese survey answered all the questions used to construct these variables. What is the most important here is the difference in risk perception between the U.S. and Japanese consumers. Figure 2 depicts the relative frequency histograms of the consumers' perceived risk level. We can see from Table 3 and Figure 2 that the Japanese consumers' perceived risk level for GM foods is higher than the U.S. consumers' level on average, and the dispersion of the risk level is also smaller for the Japanese consumers. The results of t-test and F-test indicate that there are significant differences in the mean and variance (t-value = 3.30, F-value = 2.40).

Empirical Model

Our empirical model consists of two equations: one is the equation in which the consumers' risk perception of GM foods is the dependent variable and their personal characteristics are the explanatory variables, and the other is the equation in which the WTP a premium for non-GM foods is the dependent variable and the risk perception and personal characteristics are the explanatory variables. In constructing the model, we need to take into account the following two considerations. First, the two error terms in these two equations are possibly correlated through a common but unobservable factor hidden in each error term because both the risk perception and the WTP are elicited from the same person. Hence, this model should be estimated as a system of simultaneous equations. Second, the WTP data are often obtained as interval or censored data in many CV surveys, and the risk perception data are often obtained as ordered data. The two equations can therefore be expressed as limited or discrete dependent variable models. Maddala developed a simultaneous bivariate probit model, in which the two dependent variables are binary (Maddala 1983, p.123). We expand this model to the case where one of the two dependent variables is a limited dependent variable and the other (mediating variable) is an ordered variable, and then estimate both the risk perception function and the WTP function simultaneously.

In our survey, the respondents are asked how risky they would say GM foods are in terms of risk for human health. We use their answers to this question as the risk perception variable r in our model. This r takes five values: 0 if the answer is "extremely safe," 1 if the answer is "somewhat safe," 2 if the answer is "neither risky nor safe," 3 if the answer is "somewhat risky," and 4 if the answer is "extremely risky." Their responses can be represented by an ordered choice model:

$$r^* = \boldsymbol{\beta}_r' \boldsymbol{x}_r + \varepsilon_r, \tag{4}$$

$$r = \begin{cases} 0, & \text{if} \quad r^* < 0 \\ 1, & \text{if} \quad 0 \leq r^* < \mu_1 \\ 2, & \text{if} \quad \mu_1 \leq r^* < \mu_2 \\ 3, & \text{if} \quad \mu_2 \leq r^* < \mu_3 \\ 4, & \text{if} \quad r^* \geq \mu_3 \end{cases}, \tag{5}$$

where r^* is the latent variable of r, $\boldsymbol{x}_r$ is the vector of personal characteristics related to their risk perception of GM foods, $\boldsymbol{\beta}_r$ is the coefficient vector of $\boldsymbol{x}_r$, μ_k $(k = 1,\ 2,\ 3)$ is the threshold parameter between $r = k$ and $r = k + 1$, and ε_r is the stochastic error term which follows the standard normal distribution. The vector $\boldsymbol{\beta}_r$ reflects the effects of path (b) in Figure 1.

As described in the previous section, the WTP is elicited by using a double bounded dichotomous choice format. Here, we let WTP denote the WTP a premium for a non-GM food, w_1 the response to the first choice question between a non-GM and GM foods at the same prices, and w_2 the response to the second choice question between the non-GM and GM foods at different prices. The binary variable w_k $(k = 1,\ 2)$ equals 0 if a respondent chooses the GM food and equals 1 if the respondent chooses the non-GM food. Moreover, we let t_l denote a discount on the non-GM food, which is the difference between the market price and the discounted price that is offered on the non-GM food if the respondent chose the GM food in the first question. Likewise, let t_u denote a discount on the GM food, which is the difference between the market price and the discounted price that is offered on the GM food if the respondent chose the non-GM food. Using these notations, the WTP model can be represented as

$$WTP = \boldsymbol{\beta}'_w \boldsymbol{x}_w + \alpha r + \varepsilon_w, \tag{6}$$

$$[w_1,\ w_2] = \begin{cases} [0,\ 0], & \text{if} \quad WTP \le -t_l \\ [0,\ 1], & \text{if} \quad -t_l < WTP \le 0 \\ [1,\ 0], & \text{if} \quad 0 < WTP \le t_u \\ [1,\ 1], & \text{if} \quad WTP > t_u \end{cases}, \tag{7}$$

where $\boldsymbol{x}_w$ is the vector of personal characteristics related to the WTP a premium for a non-GM food, $\boldsymbol{\beta}_w$ is the coefficient vector of $\boldsymbol{x}_w$, α is the coefficient of r, and ε_w is the stochastic error term that follows $N(0, \sigma_w^2)$. The vector $\boldsymbol{\beta}_w$ reflects the effects of path (a), and α reflects the effect of path (c) in Figure 1.

The two error terms, ε_r and ε_w, are assumed to follow a bivariate normal distribution with the correlation coefficient ρ. Then, the likelihoods of different combinations between r and $[w_1,\ w_2]$

are represented as

$$\begin{aligned}
(8)\quad P(r=j,\ w_1=0,\ w_2=0) &= \Phi_b(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-t_l - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&- \Phi_b(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-t_l - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho),\ j=0,\dots,4, \\
(9)\quad P(r=j,\ w_1=0,\ w_2=1) &= \Phi_b(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-\boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&- \Phi_b(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-t_l - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&- \Phi_b(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-\boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&+ \Phi_b(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-t_l - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho),\ j=0,\dots,4, \\
(10)\quad P(r=j,\ w_1=1,\ w_2=0) &= \Phi_b(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (t_u - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&- \Phi_b(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-\boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&- \Phi_b(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (t_u - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&+ \Phi_b(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (-\boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho),\ j=0,\dots,4, \\
(11)\quad P(r=j,\ w_1=1,\ w_2=1) &= \Phi_u(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r) - \Phi_u(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r) \\
&- \Phi_b(\mu_j - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (t_u - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho) \\
&+ \Phi_b(\mu_{j-1} - \boldsymbol{\beta}_r'\boldsymbol{x}_r,\ (t_u - \boldsymbol{\beta}_w'\boldsymbol{x}_w - \alpha r)/\sigma_w,\ \rho),\ j=0,\dots,4,
\end{aligned}$$

where Φ_u is the univariate standard normal distribution function, Φ_b is the bivariate standard normal distribution function, and $[\mu_{-1},\ \mu_0,\ \mu_4] = [-\infty,\ 0,\ \infty]$. The parameters can be estimated by using the full-information maximum likelihood (FIML) approach.

The remaining issue is how to include indifferent responses in our model. Following Kaneko and Chern (2005), the likelihoods of the indifferent responses are represented by the geometric means between the likelihood that respondents would choose the GM food and the likelihood that they would choose the non-GM food in the first question:

$$(12)\qquad \sqrt{P(r=j,\ WTP<0)}\sqrt{P(r=j,\ WTP\geq 0)},\ j=0,\dots,4.$$

The above handling of likelihood is based on the idea that it is virtually impossible that individuals continue to be indifferent between two products, and this equilibrium is therefore unstable. Since the respondents who indicate indifference tend to lean toward one or the other by chance, the likelihood of the indifferent respondents is equally split between the likelihoods of choosing the non-GM and GM food.

Results

We first estimated the risk perception functions as single equations for the U.S. and Japanese samples. Table 4 presents the parameter estimates for the ordered probit models. As is evident, O.KNOW and RELIGION are significant at the 10% and 5% levels, respectively, in the U.S. sample, but other variables are not significant. On the other hand, O.KNOW, GOVERNMENT, and ORGANIC in the Japanese sample are significant at the 5% level or better while FEMALE is marginally significant. The objective knowledge is the only determinant of risk perception that is significant in both the U.S. and Japanese samples.

A more interesting result is that the subjective knowledge does not affect the risk perception while the objective knowledge negatively affects it. This information is useful for policy makers because it is much easier for them to develop consumer education programs that increase the objective knowledge than ones that increase the subjective knowledge. In the U.S. sample, the coefficient of RELIGION variable has a negative sign. This means that consumers who think that religious concerns are important when deciding whether or not to consume GM foods tend to think that GM foods are risky at the same time. On the other hand, in the Japanese sample, the coefficients of GOVERNMENT, ORGANIC, and FEMALE have a positive sign. These results indicate that GM foods tend to be considered risky by those who have higher opinion of the government, those who often buy organic foods, and women.

Next, we present the estimation results of the simultaneous equations model for the risk perception and the WTP. For the estimation of the simultaneous equations model, the size of the U.S. sample was reduced to 70, and that of the Japanese sample to 103, by removing those respondents who did not receive the soybean oil questions and those who indicated item nonresponses. Since the number of parameters estimated simultaneously was too large for the sample size, we first estimated the risk perception and WTP functions separately and reduced the number of explanatory variables by selecting only those that attained at least 10% level of significance. Table 5 shows the estimation results of single and simultaneous equations models for the U.S. sample. In the U.S. sample, only the coefficient of RISK variable is significant and positive in the WTP function. This indicates not only that the reduction in risk perception would reduce the WTP, but also that the risk perception plays a role as a mediator between personal characteristics and the WTP. In the risk perception function, O.KNOW and FEMALE variables are significant.

Table 6 exhibits the parameter estimates of the single as well as simultaneous equations models for the Japanese sample. As it stands, the coefficient of RISK variable is significant and positive in the WTP function, which indicates that Japanese consumers' risk perception also plays a role as the mediator, just like the U.S. consumers'. Moreover, NUTRI and RECYCLE variables are included in the WTP function. The positive coefficient of NUTRI variable indicates that interest in nutrition affects the WTP in a positive way. In the second section, we predicted that the more the respondent is interested in health, the larger the WTP a premium for non-GM foods is. The above empirical result is consistent with our theoretical prediction. On the other hand, the positive coefficient of RECYCLE variable indicates that interest in environment affects the WTP in a positive way. This empirical result is not directly connected with our theoretical model, but if we replace the health risk with the environmental risk in our model, a similar interpretation as the coefficient of NUTRI variable will apply to the coefficient of RECYCLE variable. In the risk perception function, O.KNOW, GOVERNMENT, ORGANIC, RECYCLE, and FEMALE variables are significant. The coefficient of RECYCLE variable has a negative sign, which indicates that those who often recycle paper, cans, or bottles tend to think that GM foods are safe. The health risk of GM foods may be relatively small for those who are interested in environmental issues because they may be interested more in the GM plants' impacts on the ecosystem than in their health risks.

Although we estimated simultaneous equations models for the U.S. and Japanese samples, the estimation results do not necessarily support the less restricted simultaneous equations model. On the basis of Akaike Information Criterion (AIC), the single equations models are preferred to the simultaneous equations models. The correlation coefficients between error terms on the risk perception and WTP equations are not significant for the simultaneous equations model in Table 5 and 6, which suggests that the risk perception and WTP may be estimated separately from each other. This may be discouraging, but the sample size is relatively small for such a complex model as our simultaneous equations model. Furthermore, we have some evidence that the role of risk perception in the determination of WTP is not uniform among the sample (Kaneko and Chern 2006). We need to verify the present results with a larger sample.

Finally, we compare the mean WTP values between the United States and Japan. The mean WTP value can be derived from the following equation:

$$\mathrm{E}(WTP) = \sum_{k=0}^{4} \mathrm{P}(r = k | \boldsymbol{x}_r = \overline{\boldsymbol{x}}_r, \boldsymbol{\beta}_r = \hat{\boldsymbol{\beta}}_r)\alpha k + \hat{\boldsymbol{\beta}}_w \overline{\boldsymbol{x}}_w, \tag{13}$$

where $\overline{\boldsymbol{x}}_r$ and $\overline{\boldsymbol{x}}_w$ are the mean vectors of $\boldsymbol{x}_r$ and $\boldsymbol{x}_w$, and $\hat{\boldsymbol{\beta}}_r$ and $\hat{\boldsymbol{\beta}}_w$ are the estimates of $\boldsymbol{\beta}_r$ and $\boldsymbol{\beta}_w$, respectively. Table 7 shows the estimated mean WTP values. While the U.S. consumers' WTP a premium for non-GM soybean oil accounts for about 40 percent of the base price, the Japanese consumers' WTP accounts for about 97 percent of the base price. This result indicates that the Japanese consumers are much more strongly opposed to the GM soybean oil than the U.S. consumers.

Conclusion and Discussion

In this study, we examined the mediating effect of the risk perception of GM foods on the relationship between personal characteristics and the WTP a premium for non-GM soybean oil, using the U.S. and Japanese samples. First of all, we developed a theoretical model to investigate the relationship between the personal characteristics, the risk perception, and the WTP. Our theoretical results indicate that (1) the indirect impact of a personal attribute on the WTP via the link to the risk perception works in the same direction as its direct impact on the risk perception, and (2) it is possible that interests in healthy lifestyle directly affect the WTP. These theoretical expectations were confirmed by our empirical results in the end.

In the empirical analysis, we estimated a simultaneous equations model for the risk perception and the WTP. Although we have obtained a tentative result that the single equations model is statistically better than the simultaneous equations model, naturally we do not know in advance whether or not the correlation coefficient between error terms is zero. To test whether the correlation is significant or not, we need to estimate such a simultaneous model.

Our main empirical findings in both countries are (1) that consumers' risk perception plays a mediating role in the relationship between the personal characteristics and the WTP, and (2) objective knowledge of GM foods has a negative impact on the WTP, via its link to the risk perception. House et al. (2004) obtain the result that subjective knowledge of GM foods significantly affects the willingness to accept GM foods, but objective knowledge does not significantly affect the willingness to accept. Our empirical finding (2) will be more encouraging for U.S. policy makers than House et al.'s.

The average premium that Japanese consumers are willing to pay for non-GM soybean oil accounted for about 97 percent of the base price, while the average premium for the U.S. consumers accounted for about 40 percent of the base price. At present, the Japanese government does not require mandatory labeling for oils made from GM crops. However, the estimated WTP value led us to predict that the labeling rules might be extended to cover all GM foods in Japan, in the near future. The U.S. producers and policy makers will need to be prepared to deal with this situation.

Footnotes

1. We use the term "cognitive" somewhat loosely. In this paper, cognitive variables are those related to the individual's perception, attitudes, and belief.

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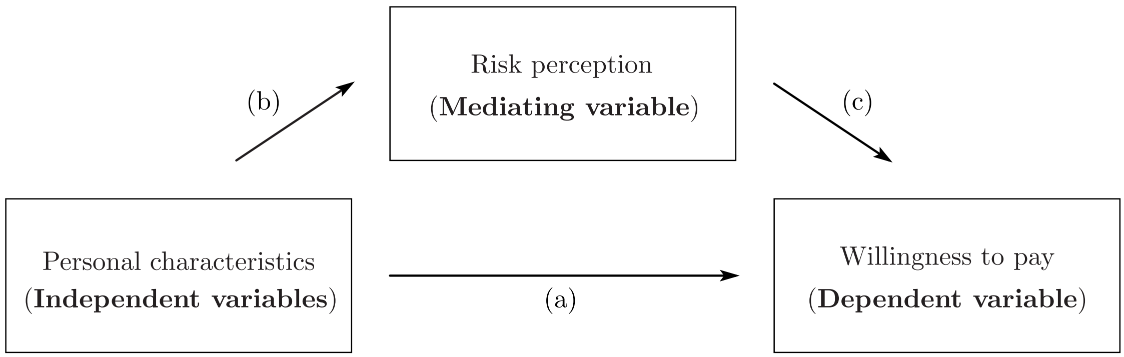

Figure 1: Conceptual Mediation Model

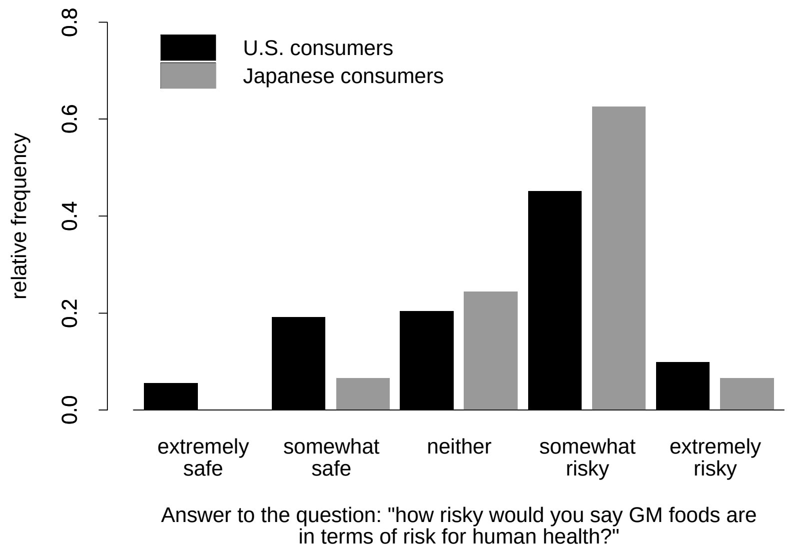

Figure 2: U.S. and Japanese Consumers' Risk Perception of GM foods

Table 1: Discounted Prices for non-GM and GM Food

	base price	5% off	10% off	20% off	30% off	50% off
U.S. survey (dollars)	1.90	1.80	1.70	1.50	1.30	1.00
Japanese survey (yen)	330	314	297	264	231	165

Table 2: Variable Definitions

Variable	Definition
Cognitive Variables	
S.KNOW	Subjective knowledge: Information level about GM foods
	1=very well informed;
	2=somewhat informed;
	3=not at all informed
O.KNOW	Objective knowledge:
	Number of correct answers to true/false questions about GM foods
RELIGION	Religious concern when consuming GM foods
	1=extremely important;
	2=somewhat important;
	3=neither important nor unimportant;
	4=somewhat unimportant;
	5=extremely unimportant
GOVERNMENT	Grade for the government's performance in food safety
	1=excellent;
	2=good;
	3=fair;
	4=poor;
	5=very poor
Habit Variables	
ORGANIC	Frequency of purchasing organic foods
	1=never;
	2=rarely;
	3=sometimes;
	4=often;
	5=always
FAFH	Frequency of purchasing fast foods or ready-made meals
	the same coding as ORGANIC
SMOKE	Frequency of purchasing cigarettes
	the same coding as ORGANIC
RECYCLE	Frequency of recycling paper, cans, or bottles
	the same coding as ORGANIC
NUTRI	Frequency of looking at the panel of nutritional information
	on food packages
	1=never;
	2=rarely;
	3=sometimes;
	4=often;
Demographic Variables	
AGE	Age in years
MARIAGE	1=married; 0 otherwise
EDUCATION	1=having a degree/graduate student; 0 otherwise
CHILD	1=with children of age 18 or younger; 0 otherwise
INCOME	The natural logarithm of income
FEMALE	1=female; 0=male

Table 3: Descriptive Statistics

Variable	U.S. sample		Japanese sample	
	Mean	Std. Dev.	Mean	Std. Dev.
Mediating Variable				
RISK	2.346	1.071	2.691	0.691
Independnet Variables				
S.KNOW	2.247	0.697	1.805	0.437
O.KNOW	1.142	0.771	1.000	0.830
RELIGION	3.253	1.446	3.659	1.093
GOVERNMENT	2.586	0.923	3.390	1.005
ORGANIC	2.340	1.121	2.976	0.900
FAFH	2.944	0.934	2.659	0.798
SMOKE	1.858	1.422	2.350	1.669
RECYCLE	3.611	1.601	4.390	0.796
NUTRI	1.630	0.912	1.675	0.647
AGE	46.864	15.028	58.122	13.139
MARIAGE	0.605	0.490	0.862	0.347
EDUCATION	0.401	0.492	0.496	0.502
CHILD	0.395	0.490	0.252	0.436
INCOME	10.786	0.830	1.686	0.615
FEMALE	0.765	0.425	0.675	0.470
Sample Size	162		123	

Table 4: Estimation Results of Risk Perception Functions

Variable	U.S. sample				Japanese sample			
	Coefficient		t-ratio	p-value	Coefficient		t-ratio	p-value
Intercept	2.900	**	1.986	0.047	−0.151		−0.090	0.928
S.KNOW	0.138		1.024	0.306	−0.195		−0.708	0.479
O.KNOW	−0.246	*	−1.934	0.053	−0.293	**	−2.021	0.043
RELIGION	−0.203	***	−3.187	0.001	−0.109		−1.074	0.283
GOVERNMENT	0.114		1.188	0.235	0.442	***	3.839	0.000
ORGANIC	0.015		0.189	0.850	0.336	**	2.393	0.017
FAFH	−0.103		−1.058	0.290	−0.053		−0.350	0.726
SMOKE	0.071		1.101	0.271	−0.009		−0.128	0.898
RECYCLE	−0.007		−0.119	0.906	−0.114		−0.774	0.439
NUTRI	0.057		0.562	0.574	−0.109		−0.605	0.545
AGE	−0.006		−0.871	0.384	0.005		0.427	0.669
MARIAGE	0.035		0.177	0.860	0.483		1.439	0.150
EDUCATION	−0.163		−0.816	0.415	0.028		0.112	0.911
CHILD	−0.256		−1.263	0.207	0.147		0.452	0.651
INCOME	−0.017		−0.146	0.884	−0.026		−0.124	0.901
FEMALE	0.123		0.564	0.573	0.522	*	1.871	0.061
μ_1	1.019	***	9.634	0.000				
μ_2	1.646	***	15.785	0.000	1.293	***	7.313	0.000
μ_3	3.223	***	20.208	0.000	3.771	***	14.185	0.000
Log-likelihood	−209.336				−101.931			
AIC	456.673				239.861			
Sample Size	162				123			

Note: The symbols ***, **, and * indicate the 1, 5, and 10 percent of significance, respectively.

Table 5: Estimation Results of Single and Simultaneous Equations Models for U.S. sample

Variable	Single equations model				Simultaneous equations model			
	Coefficient		t-ratio	p-value	Coefficient		t-ratio	p-value
Risk Perception Function								
Intercept	1.598	***	4.755	0.000	1.600	***	3.872	0.000
O.KNOW	−0.356	**	−2.066	0.039	−0.353	*	−1.889	0.059
FEMALE	0.883	***	3.030	0.002	0.871	***	3.047	0.002
μ_1	1.022	***	6.328	0.000	0.298	***	4.166	0.000
μ_2	1.533	***	9.666	0.000	0.829	***	4.238	0.000
μ_3	3.218	***	13.475	0.000	1.015	***	3.578	0.000
WTP Function								
RISK	0.306	***	4.286	0.000	1.525	***	5.069	0.000
σ	0.833	***	4.497	0.000	3.215	***	9.175	0.000
Correlation coefficient					0.087		0.399	0.690
Log-likelihood	−147.405				−147.275			
AIC	310.810				312.549			
Sample Size	70				70			

Note: The symbols ***, **, and * indicate the 1, 5, and 10 percent of significance, respectively.

Table 6: Estimation Results of Single and Simultaneous Equations Models for Japanese sample

Variable	Single equations model				Simultaneous equations model			
	Coefficient		t-ratio	p-value	Coefficient		t-ratio	p-value
Risk Perception Function								
O.KNOW	−0.249	*	−1.692	0.091	−0.249		−1.579	0.114
GOVERNMENT	0.427	***	3.810	0.000	0.428	***	3.209	0.001
ORGANIC	0.430	***	3.004	0.003	0.430	***	2.653	0.008
RECYCLE	−0.199	*	−1.855	0.064	−0.199	*	−1.688	0.091
FEMALE	0.449	*	1.723	0.085	0.448		1.524	0.128
μ_2	1.365	***	7.385	0.000	1.366	***	5.009	0.000
μ_3	3.659	***	13.829	0.000	3.659	***	9.178	0.000
WTP Function								
RECYCLE	47.738	**	2.112	0.035	46.507		1.595	0.111
NUTRI	89.720	*	1.836	0.066	89.264	*	1.745	0.081
RISK	138.188	***	2.656	0.008	140.689	*	1.950	0.051
σ	137.244	***	3.162	0.002	137.192	***	2.959	0.003
Correlation coefficient					−0.025		−0.060	0.952
Log-likelihood	−120.884				−120.881			
AIC	263.768				265.762			
Sample Size	103				103			

Note: The symbols ***, **, and * indicate the 1, 5, and 10 percent of significance, respectively.

Table 7: Estimated WTP Values

	U.S. sample		Japanese sample	
	dollars	percent[a]	yen	percent[b]
Mean WTP	0.745	0.392	305.3	0.972
95% confidence interval[c]	(0.404, 1.096)	(0.213, 0.577)	(167.5, 447.6)	(0.534, 1.426)
90% confidence interval	(0.457, 1.038)	(0.241, 0.547)	(189.8, 420.8)	(0.604, 1.340)

[a] These percentages were computed by dividing the mean WTP by the base price of 1.9 dollars.
[b] These percentages were computed by dividing the mean WTP by the base price of 314 yen.
[c] The confidence intervals were computed using Krinsky and Robb (1986) method with 10000 drawing.