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Risk Communication under Conflicting Information: The Role of Confidence in Subjective Risk Assessment

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Abstract

In this study, we develop a model of food consumption with a focus on the subjectively assessed risk of consumers and their degree of confidence in their risk assessment and use it to examine consumer behavior in the chaotic situation created by the Fukushima nuclear accident in 2011. The data were collected in March 2012 using a mail survey for 1300 Japanese women, the primary food purchasers. The respondents were asked to evaluate the cancer risk of eating agricultural products, which were assumed to be grown in the affected area, despite meeting national regulatory standards for radioactive materials, as a measure of their risk assessment and willingness to purchase Fukushima beef. The results show that the effect of confidence in a consumer's risk assessment on their behavior depends on the stated risk level: when stated risk is below an estimated critical value, termed the switching point, the risk perceived by a consumer without confidence exceeds that of one with confidence. On the other hand, perceived risk is inversely related to confidence when the stated risk exceeds the switching point.

Keywords: risk communication, perception, confidence, conflicting information, consumer behavior

1. Introduction

1.1 Introduce the Problem

The public often perceives risk to be higher than its scientifically estimated level (Riddel et al., 2003) and this overestimated risk can result in economic loss through the decreasing demand for related goods. To relieve consumer anxiety, government and industry need to deliver the correct information to consumers and gain information about what causes consumer anxiety through risk communication. In turn, effective risk communication requires an understanding of individual risk perception structures (Lofstedt, 2006; Ding et al., 2013). Unfortunately, most risk information is conflicting or ambiguous. Therefore, it is particularly important to clarify how the public perceives risk in such a situation.

For example, risk information about genetically modified organisms, food additives and pesticides usually conflict among information sources such as government, media and consumer advocacy groups. Moreover, we cannot know the exact probability of natural disasters and climate change because of scientific limitations. In such cases, risk information is ambiguous and usually reported as a range of risk estimates. Various studies addressing risk perception under conflicting or ambiguous information following Ellsberg (1961) indicate that individuals prefer an unequivocal probability option to an ambiguous probability option. Individuals also place greater weight on high-risk information when facing conflicting or ambiguous risk information (Viscusi et al., 1991; Ghosh and Ray, 1997; Viscusi, 1997). This holds even when the source of the negative information is something like a consumer advocacy group and written in a nonscientific manner (Fox et al., 2002; Hayes et al., 2002).

Several existing studies suggest the possibility that conflicting information not only reduces the probability's certainty but also violates its credibility (Smithson, 1999; Cameron 2005; Regan et al., 2014; Visschers, 2017). When this arises, the public may have to make decisions without confidence in their risk assessment. Moreover, the lack of the comprehensibility of information also makes it difficult for the public to evaluate it with confidence. Dieckmann et al. (2012), for example, argue that ambiguous risk information is difficult for laypeople to evaluate, while Johnson (2003) concludes that the public wants definitive conclusions about safety and views a range of risk estimates with some concern and distrust. Alternatively, some individuals have confidence in their own subjectively assessed risk, even if overestimated. Yet other studies find that individuals avoid information that is inconsistent with their cognitions to avoid cognitive dissonance (Meertens and Lion, 2011; Gaspar et al., 2016). Thus, individuals seeking only information that is consistent with their cognitions may also tend to have confidence in their subjective risk assessment.

However, we know little about how the confidence in subjective risk assessment affects behavior through risk perception. We regard confidence in subjective risk assessment as the distribution (i.e., ambiguity) of risk assessment. Previous studies on ambiguous information show that individuals tend to be ambiguity averse for a small probability of loss and ambiguous seeking for a large probability of loss (Einhorn and Hogarth, 1986; Hogarth and Kunreuther, 1989; Heath and Tversky, 1991; Viscusi and Chesson, 1999). The effect of confidence on an individuals' subjective risk assessment of a risk perception may also vary according to the assessed risk level.

In this study, we clarify the effect of confidence in consumer subjective risk assessment on consumer behavior. For this purpose, we analyze the consumer purchasing behavior regarding Fukushima beef in which the detection of radioactive materials resulted from the nuclear power plant accident. The Great East Japan Earthquake on March 11, 2011 damaged the Fukushima No. 1 nuclear power plant. Following the accident, radioactive materials were released into the air and detected in some agricultural and marine products from Fukushima and its adjacent prefectures. In response, the Japanese government set a regulatory limit for radioactivity in food and prohibited the distribution of foods with radiation levels exceeding this level.

Government agencies, including the Ministry of Agriculture, Forestry and Fisheries and Ministry of Health, Labor and Welfare subsequently announced that eating foods with radioactivity levels below the regulatory limit would not affect the health of consumers. The regulatory limit for radioactive substances in foods set by the Japanese government is 100 Bq/kg and this is stricter than the CODEX guideline level of 1000 Bq/kg. However, the government was unable to relieve consumer anxiety about these products, with Johnson and Chess (2003) concluding that consumers are often not reassured by claims that risk levels are below a standard value. Moreover, some parts of the media claimed that eating food from Fukushima would increase cancer risk. We argue that distrust about regulatory limits and conflicting risk information prevented Japanese consumers from assessing risk correctly and with confidence. In this analysis, we analyze how confidence in subjective risk assessment affects Japanese consumer purchasing behavior regarding Fukushima beef and clarify the effect of confidence in consumer subjective risk assessment on purchasing behavior.

2. Theory

We analyze the effect of confidence in consumer subjective risk assessment on purchasing behavior through risk perception. We suppose that confidence relates to the ambiguity of subjective risk assessment and regard it as part of a stochastically distributed subjective risk assessment. Thus, we can define an index function that expresses subjective risk assessment as the sum of the mean of subjective risk assessment , and a random variable ε that expresses the level of confidence following Riddel (2009) and Nguyen et al. (2010). The random variable ε is normally distributed with a mean of zero and a variance of σ^2, such that $\varepsilon \sim N(0, \sigma^2)$. Thus, the lower the confidence, the larger the value of σ. Equation (1) defines the index function.

$$I = m + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2) \tag{1}$$

We define consumer risk perception π as the probability that I>0. Then, we can express risk perception π as equation (2):

$$\pi = \text{prob}(I > 0) = \Phi\left(\frac{m}{\sigma}\right) \tag{2}$$

The role of confidence in forming risk perceptions could vary according to the risk level assessment of consumers. In this model, π is a decreasing (increasing) function of σ if $m > 0$ $(m < 0)$. We can thus describe the change in the role of confidence depending on m.

Next, we model the relationship between risk perception π and purchasing behavior. In terms of related work, Pennings et al. (2002) distinguish between subjective risk (risk perception) and acceptable risk level (risk attitude) in analyzing consumer responses to food safety information. In expected utility models, risk perception is the subjective probability and risk attitude is represented by the utility of each outcome (Viscusi, 1990; Zepeda et al., 2003). In this study, we express risk attitude as the acceptable risk level π' and assume that consumers avoid purchasing Fukushima beef $(y = 1)$ if the perceived risk π exceeds their acceptable risk level π', otherwise, they do not $(y = 0)$. We also assume the consumer's acceptable risk level π' is determined by explanatory variables X in the linear form $\pi' = \beta_X X + u$. We now assume that the error term u follows a standard normal distribution. We can then derive the probability of $y = 1$ and $y = 0$ as follows:

$$\mathrm{prob}(y = 1) = \Phi[\pi - \beta_X X] \quad (3)$$

$$\mathrm{prob}(y = 0) = 1 - \Phi[\pi - \beta_X X] \quad (4)$$

From equations (2), (3) and (4), we obtain the log-likelihood function as follows:

$$\log L = \sum_{y=1} \log \Phi\left[\Phi\left(\frac{m}{\sigma}\right) - \beta_X X\right] + \sum_{y=0} \log\left[1 - \Phi\left[\Phi\left(\frac{m}{\sigma}\right) - \beta_X X\right]\right] \quad (5)$$

Maximizing this log-likelihood function, we obtain the maximum likelihood estimates of the ordered probit model.

3. Survey Design and Sample

We conducted a questionnaire survey in March 2012 to collect the data necessary to estimate a probit model. We chose 1,300 subjects at random from women who are monitor members of INTAGE Inc. and sent them the questionnaire. To improve the response rate, we sent a reminder to those who did not respond (Note 1).

In the questionnaire, respondents were asked to rate the cancer risk associated with eating food with levels of radioactive materials less than the government standard using a 9-point risk ladder, as shown in Figure 1. The ratings on this scale are interpreted as follows: 9 represents the highest risk; 8 represents a risk equivalent to that derived from smoking; 7 represents a risk rating between those associated with smoking and drinking alcohol; 6 represents a risk equivalent to that derived from drinking alcohol; 5 represents a risk rating between those associated with drinking alcohol and not exercising; 4 represents a risk equivalent to that derived from a lack of exercise; 3 represents a risk rating between those associated with a lack of exercise and an insufficient intake of vegetables; 2 represents a risk equivalent to that derived from an insufficient intake of vegetables; and 1 is the lowest risk. Next, we asked respondents about their confidence in this stated risk using a 4-point scale assessment, where 4 is "without confidence," 3 is "with less confidence," 2 is "with some confidence" and 1 is "with confidence." Moreover, we asked whether respondents had avoided purchasing Fukushima beef. We also asked about their age, educational background, household income, age of the youngest child in the household, presence of elderly people in the household and the presence of relatives or friends from Fukushima as variables that possibly may influence their acceptable risk level. (Note 2) There were 879 returns.

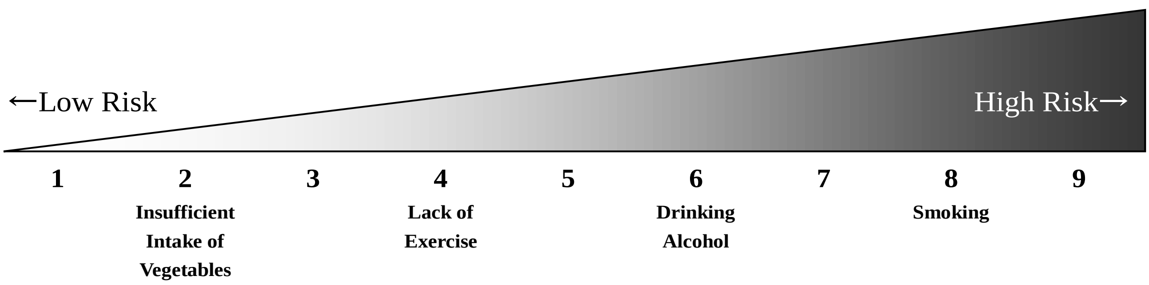

Figure 1. Risk Ladder

Table 1 summarizes the stated risk by respondent and the confidence in these assessments. First, over 50% of respondents answered that the cancer risk associated with eating foods that satisfy the regulatory limit was higher than that associated with drinking alcohol. Only 1% of respondents answered that it was lower than that associated with eating insufficient vegetables. This indicates that most respondents believe there is a higher cancer risk associated with eating foods that satisfy the regulatory limit than the risk level announced by the government. Second, about 80% of respondents did not have confidence in their subjective risk assessment. However, we also found the existence of respondents who overestimated the cancer risk with confidence. Table 2 provides the definitions and means of the variables. We can see that 54% of respondents avoided purchasing Fukushima beef. As a reference, this table also contains the mean values of the demographic variables from the national census and national survey of family income and expenditure. Comparing these values with our survey, we can see the differences are relatively large as to educational attainment, household income and the percentage of households with persons over 65 years old. We should consider these differences when interpreting the results of our analysis.

Table 1. Distribution of risk assessment by respondents and associated confidence

Stated Risk		Confidence									
		←With				Without→					
		1		2		3		4		Total	
↑	9	13	(1.5)	29	(3.3)	35	(4.0)	16	(1.8)	93	(10.6)
High	8	3	(0.3)	32	(3.6)	77	(8.8)	70	(8.0)	182	(20.7)
	7	1	(0.1)	19	(2.2)	53	(6.0)	39	(4.4)	112	(12.7)
	6	0	(0.0)	10	(1.1)	56	(6.4)	44	(5.0)	110	(12.5)
	5	0	(0.0)	12	(1.4)	60	(6.8)	62	(7.1)	134	(15.2)
	4	2	(0.2)	18	(2.0)	62	(7.1)	42	(4.8)	124	(14.1)
	3	0	(0.0)	11	(1.3)	32	(3.6)	18	(2.0)	61	(6.9)
Low	2	2	(0.2)	18	(2.0)	18	(2.0)	16	(1.8)	54	(6.1)
↓	1	1	(0.1)	4	(0.5)	2	(0.2)	2	(0.2)	9	(1.0)
Total		22	(2.5)	153	(17.4)	395	(44.9)	309	(35.2)	879	(100)

Table 2. Definitions and means of variables

		Mean	
Variables		Sample	Population
y	Avoid the purchase of Fukushima beef = 1, otherwise = 0	0.54	-
age1	Under 34 years = 1, otherwise = 0	0.21	0.20
age2	35-44 years = 1, otherwise = 0	0.22	0.17
age3	45-54 years = 1, otherwise = 0	0.20	0.14
age4	55-64 years = 1, otherwise = 0	0.26	0.18
edu1	Junior college or technical college graduate = 1, otherwise = 0	0.34	0.31
edu2	Bachelor’s, master’s or doctoral degrees = 1, otherwise = 0	0.21	0.12
log(inc)	Natural logarithm of household income	6.09	5.66
und6	Age of the youngest child is under 6 years = 1, otherwise = 0	0.14	0.17
und17	Age of the youngest child is 7-17 years = 1, otherwise = 0	0.22	0.17
ove65	Have household member over 65 years old = 1, otherwise = 0	0.32	0.37
Fkshma	Has relatives or friends from Fukushima	0.20	-

4. Estimation

4.1 Model

In this study, we aim to clarify how consumer beef purchasing behavior varies according to the assessed risk level, confidence in their subjective risk assessment, and consumer attributes. For this purpose, we estimate a probit model using the data obtained from the questionnaire survey. To start, we specify the assessed risk m using equation (6):

$$m = \alpha + r \ (\alpha < 0) \tag{6}$$

where r is the stated risk of getting cancer from eating foods that satisfy the regulatory limit and α is the switching point parameter to be estimated.(Note 3) The effect of confidence on the formation of risk perception depends on the estimate of α. Table 3 reports three cases based on the value of α. (i) When $\alpha < -9$, or equivalently, when $m > 0$ for all stated risks, risk perception π is an increasing function of σ. (ii) When $-9 \leq \alpha \leq -1$, we make a judgment about the magnitude of the effect of α on the stated risk. If the stated risk $> -\alpha$, or $m > 0$, π is an increasing function of σ. If the stated risk $= -\alpha$, or $m = 0$, π is invariant with respect to σ. If the stated risk $< -\alpha$, or $m < 0$, π is a decreasing function of σ. (iii) When $\alpha > -1$ or $m < 0, \pi$ is a decreasing function of σ for all stated risks.

Table 3. The relationship between the switching point, stated risk, risk assessment and perceived risk

Case	Range of Switching point α	Range of Stated Risk r	Sign of Risk Assessment m	Change of Risk Perception π	
				σ increase	σ decrease
i	α < -9	-9 ≤ r ≤ -1	m > 0	Increase	Decrease
ii	-9 ≤ α ≤ -1	-9 ≤ r < -α	m > 0	Increase	Decrease
		r = -α	m = 0	Invariant	Invariant
		-α < r ≤ -1	m < 0	Decrease	Increase
iii	α > -1	-9 ≤ r ≤ -1	m < 0	Decrease	Increase

We now identify the variables determining the acceptable risk level, π', for which many sociodemographic variables are possible candidates. However, we attach importance to the fact that many extant studies analyzing the relationship between sociodemographic variables and consumer responses to food safety incidents show that age, education level, income level and children significantly determine consumer behavior (Baker and Burnham, 2001; Lobb et al., 2007; Martinez-Poveda et al., 2009), and select them as deterministic variables for π'. In addition, we also include the variable indicating the existence of relatives or friends from Fukushima to control for the heterogeneity in mental distance from Fukushima. It is obvious that sociodemographic variables will affect the assessed risk level or confidence in their subjective risk assessment as well as the acceptable risk level. Therefore, in theory, the assessed risk level or confidence in the subjective risk assessment is also a function of sociodemographic variables. However, we cannot empirically identify the model when formulating assessed risk and confidence in this way. To avoid this, we ask respondents to state their level of assessed risk and confidence directly and assume that the acceptable risk level, which it is more difficult to reveal, is defined by a linear combination of the sociodemographic variables.

We specify $\beta_X X$, which represents each respondent's acceptable risk level using equation (7):

$$\beta_X X = \beta_0 + \beta_1 \text{age1} + \beta_2 \text{age2} + \beta_3 \text{age3} + \beta_4 \text{age4} + \beta_5 \text{edu1} + \beta_6 \text{edu2} + \beta_7 \log(\text{inc}) + \beta_8 \text{und6} + \beta_9 \text{und17} + \beta_{10} \text{ove65} + \beta_{11} \text{Fkshma} \quad (7)$$

where the right-hand side variables are as follows: age1 is a dummy variable equal to 1 if the respondent is between 20 and 34 years old, and 0 otherwise; age2 is a dummy variable equal to 1 if the respondent is between 35 and 44 years old, and 0 otherwise; age3 is a dummy variable equal to 1 if the respondent is between 45 and 54 years old, and 0 otherwise; and age4 is a dummy variable equal to 1 if the respondent is between 55 and 64 years old, and 0 otherwise; edu1 is a dummy variable equal to 1 if the respondent has completed junior or technical college, and 0 otherwise; edu2 is a dummy variable equal to 1 if the respondent has a university or master's degree or doctorate, and 0 otherwise; log(inc) is the natural logarithm of household income; und6 is a dummy variable equal to 1 if the youngest child in the household is six years old or younger, and 0 otherwise; und17 is a dummy variable equal to 1 if the youngest child in the household is between 7 and 17 years old, and 0 otherwise; ove65 is a dummy variable equal to 1 if the household has a member aged over 65 years, and 0 otherwise; Fkshma is a dummy variable equal to 1 if the respondent has relatives or friends from Fukushima, and 0 otherwise.

Finally, we specify the confidence in the subjective risk assessment using equation (8):

$$\sigma = \exp(\theta \text{con}) \quad (8)$$

where con is a measure of confidence in the subjective risk assessment on a 4-point scale, where 1 is "with confidence" and 4 is "without confidence." We substitute equations (6), (7) and (8) into the likelihood function (5) and estimate a probit model using the maximum likelihood method. We select the model that minimizes Akaike's information criterion (AIC) among all combinations of possible explanatory variables.

4.2 Estimation Results

The results of the full model, including all explanatory variables, and the minimum AIC model are in Table 4. The estimated coefficient of α in the minimum AIC model is -6.25 and the estimated coefficient of θ, which is the parameter on the confidence variable, is positive. The value of -6.25 is within the range of -9 to -1. As discussed, the effect of confidence on risk perception depends on the level of the stated risk in case (ii). Moreover, the switching point of -6.25 is consistent with a level of cancer risk between that derived from smoking and drinking alcohol (see Figure 1). This means that when the stated risk is below the level of risk associated with that between smoking and drinking, the risk perceived by a consumer without confidence exceeds that of one with confidence, whereas the perceived risk inversely relates to confidence when the stated risk exceeds the switching point.

The signs of the coefficients of β_1, β_2 and β_3 in the minimum AIC model are all negative. This indicates that consumers under 54 years old tend to accept higher risks than those aged 55 years old and over. The estimated coefficients of β_5 and β_6 are positive. This means that the acceptable risk level is lower among better-educated consumers. The coefficient of β_8 is negative. In other words, the acceptable risk level is lower among consumers with children less than six years old. This suggests that consumers with young children are more sensitive to food safety risks. Lastly, the coefficient of β_{11} is negative. That is, consumers who have relatives or friends from Fukushima tend to accept the risk.

Table 4. Empirical results

		Full Model			Minimum AIC Model		
Variable		coeff.	z-stat.		coeff.	z-stat.	
constant term	β_0	-0.45	-0.96		-0.06	-0.34	
age1	β_1	-0.44	-2.14	*	-0.37	-2.67	**
age2	β_2	-0.33	-1.62		-0.20	-1.64	
age3	β_3	-0.47	-2.41	*	-0.37	-2.98	**
age4	β_4	-0.02	-0.10				
edu1	β_5	0.28	2.70	**	0.29	2.82	**
edu2	β_6	0.33	2.62	**	0.34	2.79	**
log(inc)	β_7	0.08	1.05				
und6	β_8	0.24	1.63		0.19	1.41	*
und17	β_9	0.13	1.02				
ove65	β_{10}	-0.06	-0.57				
Fkshma	β_{11}	-0.26	-2.35	*	-0.25	-2.28	*
con	θ	0.20	2.40	*	0.20	2.38	*
Switching point	α	-6.27	-8.04	**	-6.25	-8.11	**
	AIC	1157.56			1152.28		
	Pseudo R^2	0.067			0.065		
	N	879			879		

5. Conclusion

Risk information is often conflicting or ambiguous. Therefore, effective risk communication requires understanding how individuals form their risk perceptions when facing conflicting and ambiguous information. We consider that conflicting or ambiguous information makes it difficult for consumers to assess risk with confidence. In this study, we resolved risk perception toward radioactive materials in food into the means of subjective risk assessment and confidence and analyzed the effect on purchasing behavior toward Fukushima beef. The reason why we focus on the confidence in subjective risk assessment is that previous studies indicate that conflicting or ambiguous information affects the means of subjective risk assessment and confidence.

All of Ghosh and Ray (1997), Viscusi (1997), Viscusi et al. (1991), Fox et al. (2002) and Hayes et al. (2002) point out that individuals place greater weight on high-risk information when facing conflicting or ambiguous risk information. Therefore, Japanese consumers probably placed greater weight on the information that claimed that eating food from Fukushima would increase cancer risk than government information and thus overestimated the risk. Smithson (1999), Cameron (2005), Regan et al. (2014), Dieckmann et al. (2012) and Visschers (2017) note that the conflict and ambiguity of information can reduce comprehensibility and violates its credibility. Thus, we expect conflicting information to confuse Japanese consumers and make it difficult for them to evaluate the risks with confidence.

In contrast, Meertens and Lion (2011) and Gaspar et al. (2016) show that individuals avoid information that is not consistent with their cognitions to avoid cognitive dissonance. This implies that individuals who seek only information that is consistent with their cognitions may tend to have more confidence in their own subjective risk assessment. In this analysis, we also showed the result of our questionnaire survey about subjective risk assessment toward Fukushima beef contaminated with radioactive materials whose risk information was conflicting along with the confidence in it. On the effect of conflicting or ambiguous information on subjective risk assessment and confidence, we confirm a similar result to the findings of previous studies. Over 50% of respondents answered that the cancer risk associated with eating foods that satisfy the regulatory limit was higher than that associated with drinking alcohol and only 1% of respondents could estimate the risk level correctly.

This suggests that Japanese consumers overestimate the risk from eating food from Fukushima. In addition, about 80% of respondents did not have confidence in their subjective risk assessment. This suggests that at the time it was difficult for Japanese consumers to assess risk with confidence because of the presence of media that reported that eating food from Fukushima would increase cancer risk alongside the lack of comprehensibility in the risk information. Nevertheless, we also found the existence of respondents who overestimated the cancer risk with confidence. These results show that conflicting or ambiguous information affects both the mean subjective risk assessment and the confidence in this subjective risk assessment.

Next, we revealed the results of the effect of subjective risk assessment and its confidence. We showed that respondents who assessed a high cancer risk from eating food from Fukushima tended to avoid purchasing Fukushima beef. Our results also showed the existence of a switching point, over which the effect of confidence changes, such that when the stated risk is below the switching point, the risk perceived by a consumer without confidence exceeds that of one with confidence, whereas the perceived risk inversely relates to confidence when the assessed risk exceeds the switching point.

Based on the above results we discuss the effective risk communication. During communication with consumers who assess the subjective risk level correctly, but without confidence, the risk communicator should focus on understanding why consumers do not have confidence in their subjective risk assessment. This will assist them to identify the method of information transmission that best helps consumers assess the risk with confidence. Information transmission using a risk ladder helping consumers understand risk information may be an effective method to increase their confidence (Loomis and DuVair, 1993; Keller, 2011).

Bronfman and Vázquez (2011) argue that a lack of knowledge strengthens the effect of trust in regulatory entities on the acceptability of hazards, so improving consumer trust in the risk communicator is especially important for consumers lacking confidence. Therefore, collaboration with a highly trustworthy group may also be an effective strategy (Dean and Shepherd, 2007). Conversely, in risk communication with consumers who overestimate the risk level with confidence, the risk communicator should focus on exploring the grounds for their confidence along with providing scientifically correct risk information. By disproving the perspective that forms the basis for their confidence, consumers may become more suspicious of their subjective risk assessment.

Verdurme and Viaene (2003) and Pinto et al. (2017) find that we need different communication strategies for different segments divided according to the level of knowledge, perceptions and behaviors to communicate effectively about risk. Our empirical results recommend dividing consumers into segments by the subjectively assessed risk level and the confidence in it. The prudent risk communicator will then improve communication efficiency by creating different risk communication strategies for each segment.

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Notes

Note 1. INTAGE is a leading market research company in Japan, conducting consumer/retail panel surveys, customer research and online surveys. As of June 2, 2014, the company had 1,985,642 active online panels throughout Japan.

Note 2. Tonsor et al. (2009) find that risk attitudes vary according to sex, age and income, but not education.

Note 3. The switching point parameter α is similar to the "crossover point" discussed by Viscusi and Chesson (1999).