Japanese consumers' valuation of domestic beef after the Fukushima Daiichi Nuclear Power Plant accident

Abstract

After the radioactive contamination of agricultural and livestock products caused by the Fukushima Daiichi Nuclear Power Plant accident of March 11, 2011, consumer aversion against purchasing food products from the affected areas has become a major social problem in Japan. We examine how test results for radioactive materials in beef affect consumer valuation of beef produced in no-risk and affected areas using a choice experiment survey of consumers in the Tokyo metropolitan area (N = 392). Respondents were divided into two groups: one faced choice experiment tasks under the current test condition (the test status was only "under the limit"), and the other faced choice experiment tasks under the tightened test condition (with three levels: "below the limit," "below one-tenth of the limit," and "undetected"). We found that consumer valuation of "below the limit" beef in the affected area did not differ from that of "below one-tenth of the limit" beef in the affected area. Introducing the tightened status improved consumer valuations of all types of beef in the no-risk area regardless of the test status. However, consumer valuation of "undetected" beef in the affected area was lower than that in the no-risk area. The same measures need to be implemented with great care in both no-risk and affected areas, failing which the effects of measures taken in the affected areas may be diluted.

Keywords: radioactive contamination; domestic beef; ordered probit model; choice experiment; willingness-to-pay (WTP)

Introduction

The Great East Japan Earthquake and the subsequent tsunami on March 11, 2011 triggered the accident at the Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Plant, which released a massive amount of radioactive materials into the environment, contaminating the air, soil, and agricultural and livestock products (Baba, 2013). After limiting the maximum permissive radiation exposure from all food products to 5 millisievert (mSv) per year (for radioactive cesium), the Japanese government set a provisional limit for each food group on March 17, 2011. It intended to regulate the shipment and intake of specific agricultural and livestock products whenever radioactive material exceeding the limit was detected (see Note 1). Although the Food Safety Commission determined that food products meeting these limits had no health effects and declared them safe (Hamada & Ogino, 2012), reputational damage became a major issue; consumers and distributors who were concerned about the risk of radioactive contamination of food refrained from purchasing agricultural and livestock products from the affected area, as they suspected them to be contaminated. Further, some non-affected production areas independently introduced tests to determine the presence of radioactive material in their agricultural and livestock products and advertised their safety to consumers.

While the risk of nuclear effects is the greatest in Fukushima, it is almost non-existent for Kagoshima, which is about 1,000 km away from Fukushima. We examine how the sociodemographic and psychological characteristics of consumers affect their aversion to consuming beef from Fukushima and Kagoshima Prefectures. Using a choice experiment, we test the effect of changes in labeling rules depicting the status of radioactive testing on consumer valuation of beef by production area. Beef was selected as the study subject; of all agricultural and livestock products, beef drew considerable social interest because 1,530-2,700 becquerel (Bq) of radioactive cesium (exceeding the then limit of 500 Bq per kilogram) was detected from the meat of 11 cows shipped from Fukushima in July 2011(MHLW, 2011). Moreover, the cause of this contamination, namely feeding cattle with rice straw containing highly concentrated radioactive material, remains unprecedented for the general public.

Kuriyama (2012) and Ujiie (2011a; 2011b; 2012) studied consumer valuation of food contaminated by this accident. Ujiie (2011a; 2011b; 2012) used the contingent valuation method to examine the relationship between the results of radioactive material tests and consumer valuations of spinach, milk, rice, and beef produced in Fukushima. Ujiie (2011a) estimated willingness to pay (WTP) for spinach from Fukushima, assuming that spinach produced at a domestic place of production without fear of contamination by a radioactive material is sold at JPY 150 per pack. Using a web survey conducted in June 2011 of 392 married women living in the Tokyo metropolitan area, the mean WTP for spinach from Fukushima containing below the limit, half of the limit or less, and no detected radioactive material, was JPY 68, JPY 71, and JPY 98 per pack, respectively. Moreover, Ujiie (2011b) estimated the WTP for beef from Fukushima, assuming that beef produced at a domestic place of production without fear of contamination by a radioactive material is sold at JPY 200 per 100 g. Using a web survey of 868 married women living in the same area in August 2011, the mean WTP for beef from Fukushima containing below the limit, half of the limit or less, one-tenth of the limit or less, one-hundredth of the limit or less, and no detected radioactive material was JPY 71, JPY 73, JPY 78, JPY 88, and JPY 118 per 100 g, respectively. These studies demonstrated that consumers perceived agricultural and livestock products labeled “contains radioactive material below the limit” and “contains radioactive material below half of the limit” as being almost equivalent. These results also revealed that consumer valuations did not improve unless the products were labeled “contains radioactive material below one-hundredth of the limit” or “radioactive material was not detected.” Thus, reputational damage could be effectively suppressed if detection levels were described in more detail and products were promoted directly to consumers when radioactivity was undetected or was below one-hundredth of the limit. Kuriyama (2012) used a choice experiment to examine consumer valuation of the level of radiation exposure from consuming rice and found that consumers were willing to pay JPY 7 per kg for reducing the amount of radiation exposure by 1 microsievert (μSv). He assumed that the relationship between the amount of exposure and consumer valuation is linear. However, Ujiie (2011a; 2011b) demonstrated that it is highly likely that consumers change their valuation according to the radiation dose.

These previous studies suffer from a limitation in that they did not consider a spillover effect, which is the effect of information regarding a good/service on the evaluation of other goods/services not directly referred to in the information (Ahluwalia, Unnava, & Burnkrant 2001; Hansen & Onozaka 2011; Roehm & Tybout 2006). In our context, this refers to how the introduction of or changes in radioactive material testing in agricultural and livestock products produced in non-affected areas—in an attempt to make consumers feel safe—would affect their valuations of products produced in affected areas.

Methods

Data

A total of 412 respondents completed the web survey conducted between September 29 and October 1, 2011, which served as the source of the data for this study. The survey was administered by Macromill, Inc., a leading Japanese online research company, which maintains a panel of more than 1.16 million Japanese consumers. Our respondents met all of the following conditions: 1) resides in the Tokyo metropolitan area (Tokyo, Chiba, Saitama, and Kanagawa Prefectures); 2) aged 20 years or older; 3) purchased beef for grilling in the past six months; and 4) is the household member who purchases beef most frequently. Panel members were invited to participate and the survey was closed once the desired number of respondents was reached.

After excluding one respondent who left some questions unanswered and 19 respondents with inconsistent cognition about the risks of consuming radioactively contaminated beef, the number of valid respondents dropped to 392. As referred to hereinafter, there are two versions of the questionnaire, which differ only in the scenario of choice experiment questions from the view point of labeling rules depicting the status of the radioactive material test (see Stage 2: Choice experiments for details). There are 196 valid respondents in each version. The average age of the valid respondents was 43, which is younger than the average age of 50 in the adult population in the area (SBJ, 2011). This is because the rate of internet usage is lower among the older age group (MIAFC, 2011). Females accounted for 79% of all valid respondents, which is significantly higher than the population average of 50%, based on the census results. This is probably because the subjects who met the fourth sampling criterion are mostly women, who are responsible for housework. The average annual household income among the valid respondents was JPY 6.79 million, which is 14% higher than the corresponding value of JPY 5.96 million among families living in the area in 2009 (SBJ, 2010).

The contents of the questionnaire were divided into six parts: anxiety for various food safety issues; purchase intentions based on the status of radioactive material tests; choice experiments for valuing beef according to the status of radioactive material tests; purchase experiences of meats before and after the accident; knowledge of and attitudes toward food safety issues, including radioactively contaminated food; and the respondent's individual and household characteristics.

Stage 1: Aversion to beef based on the status of radioactive material tests

To investigate aversion to the beef based on the status of radioactive material tests, respondents were asked how likely they were to purchase beef produced in Fukushima and Kagoshima when the radioactive material in each beef product was "untested (not tested for radioactive materials)," "below the limit (contains radioactive materials below the limit)," and "undetected (did not detect radioactive materials)." They were asked to select an option that best described their opinion: "I would not purchase beef even if it is cheap," "I would purchase beef if it is comparatively cheap," "I would purchase beef if its price is reasonable," and "I would purchase beef even if it is comparatively expensive" (see Appendix A). Using combinations of responses to each beef category, 19 respondents were excluded from the analysis because their cognition of the risk of contaminated beef was inconsistent. For example, a response combination of "I would purchase 'below the limit' Fukushima beef if it is comparatively cheap" and "I would not purchase 'undetected' Fukushima beef even if it is cheap" is inconsistent. A similar comparison was performed for other beef categories to exclude inconsistent respondents. Then, the responses were combined separately for Fukushima beef (j = f) and Kagoshima beef (j = k) into ordinal variables with four categories (see Appendix A): 1) I would purchase beef produced in area j even if it is "untested" ($Y_j = 0$); 2) I would not purchase "untested" beef produced in area j ($Y_j = 1$); 3) I would not purchase beef produced in area j even if it shows "below the limit" radioactivity ($Y_j = 2$); and 4) I would not purchase beef produced in area j even if radioactivity is "undetected" ($Y_j = 3$). Therefore, the categorical variable Y_j can be viewed as a measure of aversion to beef produced in area j based on the status of radioactive material tests. Y_j is used as the observable variable of the (latent) objective variable in the ordered probit analysis of aversion to beef and in the construction of the cutoff variables in the choice experiment analysis.

Stage 2: Choice experiments

After answering questions about their purchase intentions, respondents faced the choice experiment questions, which presented them four options for beef produced in different areas. "None of these" was added as a fifth response option (Figure 1).

Please select one of the following four types of beef that you would be most likely to purchase.
If you would not purchase any of these types, please select "none of these."

	Option 1	Option 2	Option 3	Option 4	Option 5
Product origin	Fukushima beef	Kagoshima beef	Australian beef	U.S. beef	None of these
Status of radioactive material	Below the limit	Below the limit			
Price per 100 g	JPY 698	JPY 798	JPY 198	JPY 198	
Check only one circle	○	○	○	○	○

Figure 1 Sample choice experiment question (Scenario 1)

Respondents were asked to select the beef they would be most likely to purchase. The options were differentiated along three attributes: product origin, radioactive material test result, and price (Table 1).

Table 1 Attributes and their levels.

Attribute	Levels
Product origin	Fukushima, Kagoshima, Australia, U.S.
Radioactive material testing	
Scenario 1	Fukushima: below the limit
	Kagoshima: no label (untested), below the limit
Scenario 2	Fukushima: below the limit, below one-tenth of the limit, undetected
	Kagoshima: no label (untested), undetected
Price per 100 g	Fukushima: 298, 398, 498,598, 698
(Unit: JPY)	Kagoshima: 398, 498, 598, 698, 798
	Australian and U.S.: 98, 148, 198, 248, 298

Note: As of August 2013, USD 1 = JPY 97.5.

Product origin was set as an alternative-specific attribute. Feeding cattle radioactively contaminated feed was a likely factor contributing to contamination of beef. This does not appear to have happened in Kagoshima, which is about 1,000 km away from Fukushima. Therefore, we selected the domestic production area of Kagoshima to compare against Fukushima. Given the realities of the beef market, the two domestic beef categories from both prefectures only include *Wagyu* breeds, and we set Australian and U.S. beef as the two imported beef categories. For constructing a choice situation similar to the actual purchase situation in a retail store, the respondents were informed that the only cut of beef referred to in the questions is the boned rib cut, which is suitable for *yakiniku*, a very popular type of Japanese cuisine involving grilling the meat with intense sauces. We provided no information regarding the quality of Australian and U.S. beef as these explanations are not usually provided at retail stores.

Two scenarios of the questionnaire, each with varying radioactive material test attribute settings, were created. Scenario 1 reflected the actual situation during the survey: all options for Fukushima beef were labeled “below the limit,” while those for Kagoshima beef were labeled either “below the limit” or “no label (untested)” (Figure 1). In response to the results of the tests conducted in July 2011, in which radioactive cesium exceeding the limit was detected in Fukushima beef, all cattle shipped from Fukushima (and also cattle from several neighboring prefectures) are currently tested for radioactive material. Kagoshima and many other prefectures voluntarily test some of their cattle for radioactive material. Scenario 2, which includes additional labels of hypothetical test status, includes "below the limit," "below one-tenth of the limit," or "undetected" for Fukushima beef and "no label (untested)" or "undetected" for Kagoshima beef. Compared to Scenario 1, Scenario 2 provides additional details of the test results.

The price levels were determined based on the results of a market price survey conducted prior to this study and a previous study of choice experiments using beef as the subject (Aizaki, Sawada, Sato, & Kikkawa, 2012).

A *D*-efficiency-based approach (Zwerina, Huber, & Kuhfeld, 1996) was used for creating 10 choice experiment questions for each scenario, wherein 10 questions in scenario 1 differ from those in scenario 2. All respondents faced 10 choice tasks in either scenario 1 or scenario 2. To reduce hypothetical bias, respondents were asked to read the cheap talk script before conducting these choice tasks (Van Loo, Caputo, Nayga, Metullenet, & Rick, 2011). The script is as follows: According to previous surveys, individuals' willingness to pay for a good/service tends to be larger than the amount of money they actually pay for the same good/service in a store. This is because individuals tend to be lax about hypothetical spending decisions as they do not have to actually purchase the good/service. Please answer the following questions after reflecting the extent to which you may harbor such a tendency.

Statistical analysis

Ordered probit model analysis of purchase aversion

The categorical variables Y_f and Y_k represent the respondent's aversion to Fukushima beef and Kagoshima beef, respectively, and can be regarded as ordinals based on the respondent's cognition of radiation risk. Therefore, the factors affecting aversion, according to the status of radioactive material tests, were examined using the following ordered probit model.

$$\begin{aligned} Y^*_{ji} = {} & \alpha_{oj} + \alpha_{1j}FEM_i + \alpha_{2j}AGE_i + \alpha_{3j}CJS_i + \alpha_{4j}CES_i + \alpha_{5j}CPS_i \\ & + \alpha_{6j}INC_i + \alpha_{7j}ARCF_i + \alpha_{8j}ASFD_i + \alpha_{9j}AAPE_i + \alpha_{10j}AAIE_i \\ & + \alpha_{11j}FSI_i + \alpha_{12j}FSK_i + \alpha_{13j}FST_i + e_{ji} \qquad j = \mathrm{f, k};\ i = 1,2,\cdots,N \end{aligned} \tag{1}$$

Respondent i's (unobservable) latent variable for production area j (j = f, k) is Y^*_{ji}. The latent variable and the observable variable Y_{ji} have the following relationship.

$$
\begin{aligned}
Y_{ji} &= 0 \quad \text{if} \quad Y^{*}_{ji} \leq 0 \\
&= 1 \quad \text{if} \quad 0 < Y^{*}_{ji} \leq \mu_{1j} \\
&= 2 \quad \text{if} \quad \mu_{1j} < Y^{*}_{ji} \leq \mu_{2j} \\
&= 3 \quad \text{if} \quad \mu_{2j} < Y^{*}_{ji}
\end{aligned} \tag{2}
$$

We further assume that the error term e_{ji} is normally distributed with mean 0 and variance 1. Parameter vector α and threshold parameter vector μ can be estimated using the maximum-likelihood method (Greene & Hensher, 2010).

Table 2 shows the definitions of the independent variables. It has been reported that sociodemographic variables such as gender, age, the presence of children, and household income influence consumer concerns about food safety and food purchasing behavior (Dosman, Adamowicz, & Hrudey, 2001; Lin, 1995; Nayga, 1996). Moreover, in Japan, media reports and public announcements made by the government have educated the public that the lifetime risk of dying of cancer caused by radiation exposure is higher among *younger* children and that the risk among adults becomes lower as they age, because their life expectancy becomes shorter (Gofman, 1990; Preston, Shimizu, Pierce, Suyama, & Mabuchi, 2003; UNSCEAR, 1988).

Table 2 Definition and descriptive statistics of independent variables used in the ordered probit analysis (N = 392).

Variable	Definition	Mean	S.D.
FEM	Dummy variable = 1 if the respondent is female, otherwise = 0	0.79	0.41
AGE	Age of the respondent	43.1	11.20
CJS	Dummy variable = 1 if the respondent's family includes a junior high or/and high school student, otherwise = 0	0.16	0.37
CES	Dummy variable = 1 if the respondent's family includes an elementary school student, otherwise = 0	0.15	0.36
CPS	Dummy variable = 1 if the respondent's family includes a pre-elementary school student, otherwise = 0	0.17	0.38
INC	Annual household income (Unit: million JPY)	6.79	3.30
ARCF	Degree of anxiety towards radioactively contaminated food[a]	5.60	1.39
ASFD	Degree of anxiety towards safety of feed[a]	5.15	1.25
AAPE	Degree of agreement with the statement: "I would like to support the affected area by purchasing food products produced there"[b]	4.11	1.49
AAIE	Degree of agreement with the statement: "Internal exposure by ingestion of food is inevitable to some extent now that radioactive materials have spread"[b]	4.34	1.36
FSI	Confidence in provided information about radioactive contamination of food[c]	0.00	0.97
FSK	Knowledge about radioactive material and countermeasures to contain its spread in the food supply[c]	0.00	0.91
FST	Confidence in the actions taken by the government and producers[c]	0.00	0.93

Notes: [a] These items are measured on a 7-point scale, where 1 means "No anxiety," and 7, "Very high anxiety."

[b] These items are measured on a 7-point scale, where 1 means "I completely disagree," and 7, "I completely agree."

[c] These are normalized factor scores.

For these reasons, we adopted *FEM*, *AGE*, *CJS*, *CES*, *CPS*, and *INC* as explanatory variables that may influence the respondent's aversion to Fukushima beef and Kagoshima beef. In particular, three kinds of "the presence of children"—preschool children (age 5 and below) dummy *CPS*, elementary school student (6 to 12 years) dummy *CES*, and junior or/and senior high school student (13 to 18 years) dummy *CJS*—were adopted in order to examine which age group of children influenced the aversion to beef produced in these areas. Previous research has indicated that consumers' acceptance of and purchase intentions for a particular food are also affected by their risk perception (anxiety) of the food, knowledge and attitudes, trust in sources of information, and government action (Chen, 2007; Christoph, Bruhn, & Roosen, 2008; McCarthy, O'Reilly, Cotter, & de Boer, 2004). Therefore, we adopt *ARCF*, *ASFD*, *AAPE*, *AAIE*, *FSK*, *FSI*, and *FST* as explanatory variables reflecting the respondent's degree of anxiety towards the radioactive contamination of food, the respondent's degree of anxiety towards the safety of the feed, desire to help the affected area by purchasing food products produced there, respondent's resignation to the fact that internal exposure to radioactive materials via ingestion of food is inevitable to some extent now that the materials have spread, knowledge about radioactive material and countermeasures against their spread in the food supply, confidence in the information conveyed to them about the radioactive contamination of food, and confidence in the actions being taken by the government and producers to address this contamination, respectively, which may affect the respondent's aversion to Fukushima beef and Kagoshima beef. Here, *FSI*, *FSK*, and *FST* are the scores of three factors extracted from a factor analysis of respondents' knowledge of and attitudes concerning radioactive contamination of food (see Appendix B).

The Pearson's correlation coefficients for each pair of independent variables do not exceed the scope of a reasonable limit (0.7) in terms of absolute value. The highest correlation coefficient (0.669) is observed for *FSI* and *FST*. The second-highest correlation coefficient (0.642) is found for *FST* and *AAPE*. All other correlation coefficients are below 0.5 in terms of absolute value. Therefore, we believe that a serious multicollinearity problem will not arise.

Non-compensatory choice model analysis of choice experiment tasks

In order to incorporate respondents' aversion to beef according to the status of radioactive material test into the modeling of their decision-making in the choice experiment questions, we use a non-compensatory choice model proposed by Swait (2001). This model is used to determine whether a consumer applies non-compensatory or compensatory rules while valuing the attribute variables in the utility. For example, in the context of the status of radioactive material tests, a respondents' decision "I would not purchase beef if it is untested" can be viewed as one of the non-compensatory rules of attributes. Thus, this model is suitable for our study.

Firstly, we construct a linear compensatory utility model. Respondent n is assumed to select one alternative from a choice set containing four beef alternatives and an opt-out option. Under a linear compensatory utility model, the systematic component of the utility function of option j, as Fukushima beef (j = f), Kagoshima beef (j = k), Australian beef (j = a), U.S. beef (j = u), or none of these (j = nop), is as follows.

Scenario 1:

$$V_f^c = \beta_{0f} + \beta_{pf} P_f$$
$$V_k^c = \beta_{0k} + \beta_{4k} R1_k + \beta_{pk} P_k$$
$$V_a^c = \beta_{0a} + \beta_{pa} P_a \qquad (3)$$
$$V_u^c = \beta_{0u} + \beta_{pu} P_u$$
$$V_{nop}^c = 0$$

Scenario 2:

$$V_f^c = \gamma_{0f} + \gamma_{4f} R2_f + \gamma_{8f} R3_f + \gamma_{pf} P_f$$
$$V_k^c = \gamma_{0k} + \gamma_{4k} R3_k + \gamma_{pk} P_k$$
$$V_a^c = \gamma_{0a} + \gamma_{pa} P_a \qquad (4)$$
$$V_u^c = \gamma_{0u} + \gamma_{pu} P_u$$
$$V_{nop}^c = 0$$

where $R1_k$, $R2_f$, and $R3_j$ (j = f, k) are alternative-specific dummy variables for the label showing the status of radioactive material tests: $R1_k = 1$, $R2_f = 1$, and $R3_j = 1$ indicate that the Kagoshima beef was labeled "below the limit," the Fukushima beef was labeled "below one-tenth of the limit," and the beef produced in area j was labeled "undetected." Else, the variables take the value 0; P_j (j = f, k, a, u) denotes alternative-specific attribute variables showing the price of beef produced in area j (unit: JPY per 100 g); β_{0j} (j = f, k, a, u) are alternative specific constants; and the other βs and γs are coefficients to be estimated.

The non-compensatory choice model permits us to assume that while respondents have (un)acceptable conditions of attributes (i.e., rules), such rules are occasionally violated. For example, although some respondents may decide, as a rule, to purchase only domestic beef, they may occasionally violate it and purchase imported beef. Under the non-compensatory choice model proposed by Swait (2001), these rules and violations are expressed in the utility function using special dummy variables (i.e., cutoff variables) and their estimated coefficients. Let us consider the rule that a respondent *does not* purchase beef that has an undesirable feature for him/her (all the rules in our study are of this type), e.g., the rule in this case would be "I do not purchase untested beef." The cutoff variable corresponding to the rule takes the value 1 if the respondent chooses to follow the rule and if the beef that is included in the respondent's choice set has a feature undesirable to him/her, and 0 otherwise. Thus, it should be noted that the cutoff variable depends on both the beef attribute and the respondent's rule. Since the cutoff variable reflects the respondent's attitude toward an undesirable feature of the beef, the coefficient of the cutoff variable is expected to be negative. If the concerned respondent adheres strictly to the rule and the extent of undesirability is extremely large for him/her, the estimated coefficient of the cutoff variable would be an extremely large negative value. If the respondent does not adopt the rule while making his/her choice, the estimated coefficient would be a small negative value or 0.

We introduce two categories of cutoff variables: respondents' experiences of purchasing beef according to product origin and respondents' aversion to beef according to the status of radioactive material tests. Since some Japanese consumers are averse to specific product origins for a particular food product because of safety concerns or its taste (e.g., Aizaki, Sawada, Sato, & Kikkawa, 2012; Peterson & Yoshida, 2004), we create dummy variables NPE_{w}, NPE_{a}, and NPE_{u}, representing the *no* purchase experience of domestic beef, Australian beef, and U.S. beef, respectively. Here, 1 indicates that the respondent had *not* purchased beef of the respective product origin in the past, and 0, otherwise. We can consider a respondent's no-purchase experience of beef as his/her revealed rule of aversion to purchasing beef according to product origin. The second category of cutoff variables includes $DY1_j$, $DY2_j$, and $DY3_j$ (j = f, k), which are dummy variables representing the aversion to purchasing beef according to the status of radioactive material tests. $DY1_j = 1$, $DY2_j = 1$, and $DY3_j = 1$ indicate that the respondent shows aversion to "untested" beef produced in area j, to "under the limit" beef produced in area j, and (even) to "undetected" beef produced in area j, respectively. Else, the variables take the value 0, which means that the respondent has no aversion to beef produced in area j. We can consider the respondent's intention not to purchase beef as his/her stated rule of aversion to purchasing beef according to the status of radioactive material tests.

Under the non-compensatory choice model and the cutoff variables mentioned above, the systematic component of the utility function of each option is given as:

Scenario 1:

$$
\begin{aligned}
V_{\mathrm{f}}^{\mathrm{nc}} &= \beta_{0\mathrm{f}} + \beta_{\mathrm{nw}} NPE_{\mathrm{w}} + \beta_{1\mathrm{f}} DY1_{\mathrm{f}} + \beta_{2\mathrm{f}} DY2_{\mathrm{f}} + \beta_{3\mathrm{f}} DY3_{\mathrm{f}} + \beta_{\mathrm{pf}} P_{\mathrm{f}} \\
V_{\mathrm{k}}^{\mathrm{nc}} &= \beta_{0\mathrm{k}} + \beta_{\mathrm{nw}} NPE_{\mathrm{w}} + \beta_{1\mathrm{k}} DY1_{\mathrm{k}} + \beta_{2\mathrm{k}} DY2_{\mathrm{k}} + \beta_{3\mathrm{k}} DY3_{\mathrm{k}} + \beta_{4\mathrm{k}} R1_{\mathrm{k}} + \beta_{5\mathrm{k}} R1_{\mathrm{k}} \times DY1_{\mathrm{k}} \\
&\quad + \beta_{6\mathrm{k}} R1_{\mathrm{k}} \times DY2_{\mathrm{k}} + \beta_{7\mathrm{k}} R1_{\mathrm{k}} \times DY3_{\mathrm{k}} + \beta_{\mathrm{pk}} P_{\mathrm{k}} \qquad (5) \\
V_{\mathrm{a}}^{\mathrm{nc}} &= \beta_{0\mathrm{a}} + \beta_{\mathrm{na}} NPE_{\mathrm{a}} + \beta_{\mathrm{pa}} P_{\mathrm{a}} \\
V_{\mathrm{u}}^{\mathrm{nc}} &= \beta_{0\mathrm{u}} + \beta_{\mathrm{nu}} NPE_{\mathrm{u}} + \beta_{\mathrm{pu}} P_{\mathrm{u}} \\
V_{\mathrm{nop}}^{\mathrm{nc}} &= 0
\end{aligned}
$$

Scenario 2:

$$\begin{aligned}
V_{f}^{nc} &= \gamma_{0f} + \gamma_{nw}\, NPE_{w} + \gamma_{1f}\, DY1_{f} + \gamma_{2f}\, DY2_{f} + \gamma_{3f}\, DY3_{f} + \gamma_{4f}\, R2_{f} + \gamma_{5f}\, R2_{f}\times DY1_{f} \\
&\quad + \gamma_{6f}\, R2_{f}\times DY2_{f} + \gamma_{7f}\, R2_{f}\times DY3_{f} + \gamma_{8f}\, R3_{f} + \gamma_{9f}\, R3_{f}\times DY1_{f} \\
&\quad + \gamma_{10f}\, R3_{f}\times DY2_{f} + \gamma_{11f}\, R3_{f}\times DY3_{f} + \gamma_{pf}\, P_{f} \\
V_{k}^{nc} &= \gamma_{0k} + \gamma_{nw}\, NPE_{w} + \gamma_{1k}\, DY1_{k} + \gamma_{2k}\, DY2_{k} + \gamma_{3k} DY3_{k} + \gamma_{4k}\, R3_{k} + \gamma_{5k} R3_{k}\times DY1_{k} \\
&\quad + \gamma_{6k} R3_{k}\times DY2_{k} + \gamma_{7k} R3_{k}\times DY3_{k} + \gamma_{pk}\, P_{k} \\
V_{a}^{nc} &= \gamma_{0a} + \gamma_{na}\, NPE_{a} + \gamma_{pa}\, P_{a} \\
V_{u}^{nc} &= \gamma_{0u} + \gamma_{nu}\, NPE_{u} + \gamma_{pu}\, P_{u} \\
V_{nop}^{nc} &= 0
\end{aligned} \tag{6}$$

Since the non-compensatory choice model can be integrated into any discrete choice models, we use the error components multinomial logit (ECMNL) model to analyze the responses to the choice experiment tasks. It is a type of flexible discrete choice model incorporating other probability terms into a multinomial logit (MNL) model, to relax the assumption of the independence of irrelevant alternative that exists within the MNL model (Brownstone, Bunch, & Train, 2000). This model has been applied in recent empirical studies using choice experiments (MacDonald, Morrison, Rose, & Boyle, 2011; Marcucci & Gatta, 2011). Under the ECMNL model integrated with the non-compensatory choice model, the utility function of each option is specified as follows:

Scenario 1:

$$\begin{aligned}
U_{f}^{nc} &= V_{f}^{nc} + \varepsilon_{f} + \theta_{f}\, E_{f} \\
U_{k}^{nc} &= V_{k}^{nc} + \varepsilon_{k} + \theta_{k}\, E_{k} \\
U_{a}^{nc} &= V_{a}^{nc} + \varepsilon_{a} + \theta_{a}\, E_{a} \\
U_{u}^{nc} &= V_{u}^{nc} + \varepsilon_{u} + \theta_{u}\, E_{u} \\
U_{nop}^{nc} &= \varepsilon_{nop} + \theta_{nop}\, E_{nop}
\end{aligned} \tag{7}$$

Scenario 2:

$$\begin{aligned}
U_{f}^{nc} &= V_{f}^{nc} + \xi_{f} + \omega_{f}\, E_{f} \\
U_{k}^{nc} &= V_{k}^{nc} + \xi_{k} + \omega_{k}\, E_{k} \\
U_{a}^{nc} &= V_{a}^{nc} + \xi_{a} + \omega_{a}\, E_{a} \\
U_{u}^{nc} &= V_{u}^{nc} + \xi_{u} + \omega_{u}\, E_{u} \\
U_{nop}^{nc} &= \xi_{nop} + \omega_{nop}\, E_{nop}
\end{aligned} \tag{8}$$

where ε_j is independent and identically type I extreme value distributed. E_j is an error component that assumes random respondent effects specific to choice j and averages to 0. The parameter vectors β, γ, θ, and ω in each ECMNL model are estimated using the maximum simulated likelihood method (Train, 2003). The estimations are conducted using NLOGIT 5.0 (Econometric Software, 2012).

Results

Ordered probit analysis

Table 3 shows the respondents' aversion to Fukushima and Kagoshima beef according to the status of radioactive material tests. A high percentage (81%) showed aversion to "untested" Fukushima beef, that is, they stated that they would not purchase it. While this figure drops to 33% when Fukushima beef was labeled "below the limit," 25% showed aversion even "undetected" Fukushima beef, suggesting that many consumers have a strong fear of radioactively contaminated beef. Conversely, 23% showed aversion to "untested" Kagoshima beef. The figure declines significantly (to 6%) when Kagoshima beef was labeled "below the limit" and is 3% when it was labeled "undetected."

Table 3 Respondents' aversion to Fukushima and Kagoshima beef according to the test status (N = 392).

Test status	Averse to Fukushima beef		Averse to Kagoshima beef	
	n	%	*n*	%
Untested	317	81	92	23
Below the limit	129	33	22	6
Undetected	99	25	11	3

Tables 4 and 5 show the results of the ordered probit model analysis and the marginal effect of each independent variable calculated from the results, respectively.

Table 4 Ordered probit model analysis of respondents' aversion to Fukushima beef according to the status of radioactive material tests (N = 392).

Variable	Coefficient	S.E.	Marginal effects at means			
			Prob[Y_f = 0]	Prob[Y_f = 1]	Prob[Y_f = 2]	Prob[Y_f = 3]
Constant	0.424	0.521				
FEM[a]	0.271 *	0.161	−0.050	-0.030 **	0.021	0.058 *
AGE	−0.016 ***	0.006	0.003 **	0.002 **	−0.001 **	−0.004 **
CJS[a]	0.122	0.178	−0.019	−0.020	0.009	0.030
CES[a]	0.045	0.173	−0.007	−0.007	0.003	0.011
CPS[a]	0.334 *	0.176	−0.048 **	−0.063	0.025 *	0.087 *
INC	0.031	0.019	0.007	−0.005	0.002	0.007
ARCF	0.495 ***	0.064	−0.083 ***	−0.072 **	0.039 ***	0.116 ***
ASFD	−0.083	0.065	0.014	0.012	−0.007	−0.020
AAPE	−0.257 ***	0.057	0.043 ***	0.037 ***	−0.020 ***	−0.060 ***
AAIE	−0.046	0.049	0.008	0.007	−0.004	−0.011
FSI	0.207 **	0.090	−0.034 **	−0.029 **	0.016 **	0.047 **
FSK	0.120 *	0.123	−0.018	−0.016	0.009	0.026
FST	−0.484 ***	0.110	0.079 ***	0.069 ***	−0.037 ***	−0.111 ***
Threshold parameter						
μ_1	2.020 ***	0.079				
μ_2	2.354 ***	0.083				

Notes: χ^2_{13} = 254.97 ***, McFadden's R^2 = 0.240.
For Tables 4 and 5, *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.
[a] For Tables 4 and 5, the marginal effects due to dummy variables are analyzed by taking the difference of estimated probabilities between the different levels of the dummy covariates.

Overall, females (*FEM*) were more likely to be averse to Fukushima beef than males. The probability of females refusing to purchase "undetected" Fukushima beef was higher. Females showed a similar tendency for Kagoshima beef. For example, the probability of them showing no aversion to "untested" Kagoshima beef was significantly lower than that of the males. Overall, aversion to Fukushima beef became significantly weaker with aging (*AGE*). The probability of showing no aversion to "untested" Fukushima beef was significantly higher, and the probability to refuse to purchase "undetected" Fukushima beef was significantly lower with aging. Respondents with preschool children (*CPS*) showed stronger aversion to Fukushima beef than others. The probability of them having no aversion to "untested" Fukushima beef was significantly lower, and the probability of refusing to purchase "undetected" Fukushima beef was higher.

Table 5 Ordered probit model analysis of respondents' aversion to Kagoshima beef according to the status of radioactive material tests (N = 392).

Variable	Coefficient	S.E.	Marginal effects at means			
			Prob[Y_f = 0]	Prob[Y_f = 1]	Prob[Y_f = 2]	Prob[Y_f = 3]
Constant	−1.997 ***	0.662				
FEM[a]	0.400 *	0.205	−0.102 **	0.077 **	0.013 **	0.012 *
AGE	−0.006	0.007	0.002	−0.001	0.000	0.000
CJS[a]	0.196	0.203	−0.059	0.042	0.009	0.008
CES[a]	−0.223	0.208	0.059	−0.044	−0.008	−0.007
CPS[a]	0.178	0.198	−0.053	0.038	0.008	0.007
INC	0.011	0.022	−0.003	0.002	0.000	0.000
ARCF	0.072	0.077	−0.020	0.015	0.003	0.003
ASFD	0.225 ***	0.079	−0.064 ***	0.047 ***	0.009 **	0.008 **
AAPE	−0.025	0.064	0.007	−0.005	−0.001	−0.001
AAIE	−0.106 **	0.054	0.030 **	−0.022 **	−0.004 *	−0.004 *
FSI	0.067	0.102	−0.019	0.014	0.003	0.002
FSK	0.192 **	0.085	−0.055 **	0.040 **	0.008 **	0.007 **
FST	−0.170	0.125	0.048	−0.035	−0.007	−0.006
Threshold parameter						
μ_1	0.994 ***	0.104				
μ_2	1.358 ***	0.136				

Notes: χ^2_{13} = 53.63 ***, McFadden's R^2 = 0.096.

Anxiety toward radioactively contaminated food (*ARCF*) significantly increased aversion to Fukushima beef. Larger *ARCF* values lowered the probability of showing no aversion to "untested" Fukushima beef and raised the probability of refusing "undetected" Fukushima beef. Conversely, respondents' aversion to Kagoshima beef was affected by their anxiety toward the safety of the feed (*ASFD*). The likelihood of showing no aversion to "untested" Kagoshima beef was lower among individuals with greater anxiety toward the safety of the feed. This is probably because the mass media would have alerted the public that radiation-contaminated feed was circulating across a wide area beyond the affected area. Further, individuals with a stronger desire to help the affected area by purchasing food products produced there (*AAPE*) showed weak aversion to "untested" Fukushima beef and had lower probability of refusing to purchase "undetected" Fukushima beef. Individuals who have resigned themselves to the fact that internal exposure by ingestion of food is inevitable due to the spread of radioactive materials in the food chain (*AAIE*) were relatively more likely to show no aversion to "untested" Kagoshima beef. *AAIE* had no observable effect on the aversion to Fukushima beef.

Individuals expressing higher confidence in the information provided by various sources on the radioactive contamination of food (*FSI*) had stronger aversion to Fukushima beef. They were less likely to show no aversion to "untested" Fukushima beef and more likely to refuse to purchase "undetected" Fukushima beef. The information about the safety of food produced in Fukushima area presented through various media at the time of the survey varied; some of it was positive (reassuring the respondents), while some of it was negative (creating anxiety among them). Negative information was the primary factor in decision making by the respondents; this is probably because people tend to err on the side of caution. Individuals who have confidence in the actions taken by the government and producers to address radioactive contamination in food (*FST*) showed significantly less aversion to Fukushima beef. Given that knowledge on radioactive material and countermeasures against their spread to the food supply (*FSK*) did not show a significant effect on the aversion, it appears that their aversion is more likely to be influenced by the trustworthiness of the government's/producers' actions to address radioactive contamination than their own knowledge. While *FSI* and *FST* showed no significant effect on the aversion to Kagoshima beef, higher *FSK* confirmed significant aversion.

Choice experiment analysis

Table 6 shows the frequency of selection for each option in the choice experiment questions in Scenarios 1 and 2. Of the five options, the relative frequency of selection was the highest for Australian beef in both scenarios, and it was higher in Scenario 2 (46%) than in Scenario 1 (43%). Conversely, for Fukushima beef (all types), the relative frequency of selection was lower in Scenario 2 (9%) than in Scenario 1 (13%). This result suggests that describing additional details of radioactive material tests on the label generally does not improve consumer valuation of Fukushima beef. In order to examine the influence that each additional detail of the test result has on the consumer valuation of Fukushima beef, let us look into the statistical analysis results on the response data from the choice experiments.

Table 6 Frequency of selection for each option in the choice experiment tasks.

Option	Scenario 1		Scenario 2	
	n	%	*n*	%
Fukushima beef	245	13	174	9
Kagoshima beef	283	14	364	19
Australian beef	849	43	897	46
U.S. beef	365	19	382	19
None of these	218	11	143	7
Total	1,960	100	1,960	100

Table 7 shows the results of the ECMNL model analysis of the choice experiments. We exclude some interaction terms between attribute dummy variables (the status of radioactive material tests) and respondent characteristic variables (aversion to beef) from the final model because they produced unstable results. These unstable results may have occurred since the interaction terms that are not included in the final model rarely take the value 1.

Table 7 ECMNL model analysis of responses to choice experiment tasks.

Variable	Scenario 1			Scenario 2		
	Coefficient		S.E.	Coefficient		S.E.
ASC_f	9.679	***	0.845	7.105	***	0.870
ASC_k	5.609	***	0.763	8.420	***	0.749
ASC_a	6.158	***	0.450	5.979	***	0.463
ASC_u	5.750	***	0.506	5.956	***	0.492
NPE_w	−5.354	***	0.981	−4.195	***	0.658
NPE_a	−6.715	***	0.738	−4.964	***	0.719
NPE_u	−6.571	***	1.457	−5.091	***	0.594
P_f	−1.331	***	0.093	−1.174	***	0.126
P_k	−1.089	***	0.077	−1.269	***	0.095
P_a	−0.864	***	0.073	−1.029	***	0.091
P_u	−1.559	***	0.117	−1.434	***	0.120
$DY1_f$	−3.155	***	0.720	−2.040	***	0.688
$DY2_f$	−5.547	***	1.387	−6.558	***	2.121
$DY3_f$	−9.159	***	2.229	−4.947	**	2.223
$R2_f$	-			0.302		0.339
$R2_f \times DY3_f$	-			−1.761		1.859
$R3_f$	-			1.407	***	0.311
$R3_f \times DY3_f$	-			−0.154		1.854
$DY1_k$	1.137		0.947	−1.191		0.773
$DY2_k$	2.394		2.264	−1.099		2.116
$DY3_k$	2.764	**	1.382	-		
$R1_k$	1.126	***	0.190	-		
$R1_k \times DY1_k$	0.671	*	0.345	-		
$R1_k \times DY2_k$	−3.713		2.374	-		
$R1_k \times DY3_k$	−4.029	***	0.921	-		
$R3_k$	-			1.218	***	0.210
Error component						
E_f	3.227	***	0.423	2.727	***	0.380
E_k	3.117	***	0.384	3.226	***	0.405
E_a	1.771	***	0.234	1.230	***	0.226
E_u	1.146	***	0.306	0.886	***	0.268
E_{nop}	−3.225	***	0.431	2.402	***	0.403
Log likelihood value	−1641.4			−1682.6		
McFadden's R^2	0.480			0.467		
Replications	500			500		
Sample size	196			196		
Observations	1960			1960		

Notes: ASC_j is an alternative-specific constant for each option j (β_{0j} or γ_{0j}).

*** denotes $p < 0.01$, ** denotes $p < 0.05$, * denotes $p < 0.10$.

- : The applicable variable is not included in the model.

The results in both questionnaire scenarios show that the estimated coefficient of the price of beef (P_j) was negative ($p < 0.01$): a price increase reduces the utility of beef. The dummy variable indicating whether a respondent has a purchasing habit (NPE_j) had a negative coefficient ($p < 0.01$); no experience of purchasing beef j in the past is associated with an enhanced likelihood of aversion to the applicable beef.

Consider the attributes of the radioactive material test. Since all the Fukushima beef was "below the limit" in Scenario 1, the results that each coefficient of $DY1_{\mathrm{f}}$, $DY2_{\mathrm{f}}$, and $DY3_{\mathrm{f}}$ is significantly negative, meaning that respondents averse to "untested" or "below the limit" Fukushima beef or who show aversion to even "undetected" Fukushima beef, place less value on "below the limit" Fukushima beef compared to those who have no aversion to "untested" Fukushima beef. We applied "untested" and "below the limit" levels for Kagoshima beef in Scenario 1. Respondents averse to "untested" or "below the limit" Kagoshima beef have similar preferences to those without aversion to "untested" Kagoshima beef, because the coefficients of $DY1_{\mathrm{k}}$ and $DY2_{\mathrm{k}}$ are not significantly different from 0. The coefficient of $DY3_{\mathrm{k}}$ is significantly positive; the choice probability of "untested" Kagoshima beef for those averse to even "undetected" Kagoshima beef is larger than that for others. Such increased choice probability seems to be inconsistent with their attitude toward the test status and could have resulted because only 11 respondents (3% of the total) show aversion to "undetected" Kagoshima beef. The main effect of $R1_{\mathrm{k}}$ was significantly positive (1.126, $p < 0.01$), implying that the "below the limit" label increases the utility level among respondents with zero interaction (respondents averse to Kagoshima beef even if it is "untested"). Of the respondents whose interaction was not 0, those averse to "untested" Kagoshima beef had a significantly positive ($p < .10$) interaction ($R1_{\mathrm{k}} \times DY1_{\mathrm{k}}$). However, those averse to even Kagoshima beef labeled "undetected" have a negative interaction ($R1_{\mathrm{k}} \times DY3_{\mathrm{k}}$), its absolute value (–4.029) being larger than the main effect (1.126). Thus, the additional value of "below the limit" is not recognized for those averse to even "undetected" Kagoshima beef.

The attribute of the radioactive material test in Scenario 2 included three levels for Fukushima beef—"below the limit," "below one-tenth of the limit," and "undetected"—and two levels for Kagoshima beef: "below the limit" and "undetected." For Fukushima beef, whereas the main effect of "below one-tenth of the limit" ($R2_{\mathrm{f}}$) is not significantly different from 0, that of "undetected" ($R3_{\mathrm{f}}$) is significantly larger than 0. This means that consumer valuation of "below the limit" Fukushima beef is not different from that of "below one-tenth of the limit" Fukushima beef, and the valuation of “undetected” Fukushima beef is larger than that of “below the limit” or “below the one-tenth of the limit” Fukushima beef. For Kagoshima beef, the main effect of the “undetected” label ($R3_k$) was significantly positive; the “undetected” label improves consumer utility more than the “untested” label.

Table 8 shows the representative respondent’s WTP for each beef type. “Representative respondents” would be averse to buying “untested” Fukushima beef ($DY1_f = 1$), have no aversion to even “untested” Kagoshima beef ($DY1_k = DY2_k = DY3_k = 0$), and have purchased U.S. beef, Australian beef, and Japanese *Wagyu* beef ($NPE_w = NPE_a = NPE_u = 0$) in the past. WTP reveals how much representative respondents are willing to pay in order to purchase the given beef rather than purchasing “none of these” (Lusk & Schroeder, 2004). WTP per 100 g for “below the limit” Fukushima beef under Scenario 1 and Scenario 2 is JPY 490 and JPY 433, respectively. There is no statistical difference between these two values according to the method of Poe, Giraud, & Loomis (2005). WTP for the “undetected” Fukushima beef under Scenario 2 is JPY 553 per 100 g. Although the figure is significantly different from that of “below the limit” Fukushima beef under Scenario 2, it is not significantly different from the WTP values for “below one-tenth of the limit” Fukushima beef in Scenario 2 and “below the limit” Fukushima beef in Scenario 1. Conversely, WTP per 100 g of “untested” and “below the limit” Kagoshima beef is JPY 515 and JPY 618, respectively, with no significant difference between the two. WTP per 100 g for “untested” and “undetected” Kagoshima beef under Scenario 2 is JPY 664 and JPY 760, respectively, with a statistically significant difference.

Table 8 Representative respondents' WTP for each beef type (Unit: JPY per 100 g).

Beef type	Scenario	Product origin	Status of radioactive material	WTP	Significant pairwise differences in WTP by beef type
(1)	1	Fukushima beef[a]	Below the limit	490 [395, 587]	(1) > (5), (12) (1) < (3), (4), (9), (10),(11)
(2)	1	Kagoshima beef[b]	Untested	515 [387, 646]	(2) > (5), (12) (2) < (4), (9), (10), (11)
(3)	1	Kagoshima beef[b]	Below the limit	618 [497, 747]	(3) > (1), (5), (6), (7), (12) (3) < (10)
(4)	1	Australian beef	Untested	645 [526, 777]	(4) > (1), (2), (5), (6), (7), (12) (4) < (10)
(5)	1	U.S. beef	Untested	369 [312, 430]	(5) < (1), (2), (3), (4), (7), (8), (9), (10), (11)
(6)	2	Fukushima beef[a]	Below the limit	433 [322, 551]	(6) < (3), (4), (8), (9), (10), (11)
(7)	2	Fukushima beef[a]	Below the one-tenth of the limit	459 [351, 580]	(7) > (5) (7) < (3), (4), (9), (10), (11)
(8)	2	Fukushima beef[a]	Undetected	553 [443, 675]	(8) > (5), (6), (12) (8) < (9), (10)
(9)	2	Kagoshima beef[b]	Untested	664 [578, 754]	(9) > (1), (2), (5), (6),(7), (8), (12) (9) < (10)
(10)	2	Kagoshima beef[b]	Undetected	760 [673, 852]	(10) > (1), (2), (3), (4), (5), (6), (7), (8), (9), (11), (12)
(11)	2	Australian beef	Untested	583 [495, 684]	(11) > (1), (5), (6), (7), (12) (11) < (10)
(12)	2	U.S. beef	Untested	416 [358, 481]	(12) < (1), (2), (3), (4), (8), (9), (10), (11)

Notes: [a] Representative respondents' aversion to Fukushima beef is expressed as "I will purchase it if below the limit."
[b] Representative respondents' aversion to Kagoshima beef is indicated as "I will purchase it even if untested."
Figures in brackets indicate the lower and upper values of the 95% confidence interval for each WTP, calculated according to the Krinsky & Robb (1986) procedure with 10,000 draws.
The Poe, Giraud, & Loomis (2005) one-sided combinatorial test was used to detect pairwise significant differences ($p < 0.10$) in WTP by beef type.

WTP per 100 g of Australian beef under Scenario 1 and Scenario 2 is JPY 645 and JPY 583, respectively, with no significant difference between the two. WTP for U.S. beef under Scenario 1 and Scenario 2 is JPY 369 and JPY 416, respectively, with no significant difference between the two. WTP for Australian beef is significantly larger than WTP for U.S. beef under both Scenario 1 and Scenario 2. Detailing the status of radioactive material tests on domestic beef could not change the respondents' valuation of imported beef. The WTP for Australian beef is significantly larger than "below the limit"

Fukushima beef and “untested” Kagoshima beef under Scenario 1. Also, it is significantly larger than “below the limit” and “below the one-tenth of the limit” Fukushima beef under Scenario 2. Only WTP for “undetected” Kagoshima beef under Scenario 2 is significantly larger than the WTP for Australian beef. These findings suggest that the radioactive contamination accident may have decreased Japanese consumers’ valuation of domestic *Wagyu* beef relative to Australian beef (Yoshida, 2013), which is consistent with the result shown in Table 6.

Discussion and conclusion

According to significant marginal effects, the ordered probit model analysis revealed that consumer *anxiety towards radioactive contamination of food* and *confidence in the actions taken by the government and producers* affected their aversion to Fukushima beef. Thus, to mitigate excessive risk aversion behavior towards Fukushima beef, it is essential to win public trust by upscaling countermeasures taken against radioactive contamination of food.

Twenty-three percent of respondents showed aversion to “untested” Kagoshima beef (Table 3). Kagoshima Prefecture does not test its own agricultural and livestock products for radioactive material, since there was no change in the amount of radiation in the environment before and after the accident. Thus, it is highly unlikely that radioactive material could have contaminated the feed (see Note 2). The fact that approximately one-fourth of respondents still showed a negative attitude towards Kagoshima beef indicates the magnitude of the effect of this accident. However, the choice experiment did not indicate that the attitude of not wanting to purchase “untested” Kagoshima beef had a significant impact on deciding to purchase “untested” Kagoshima beef. Since the survey period coincided with the end of September 2011, people may have had access to more information than they did immediately after radioactively contaminated beef was discovered in early July 2011, thus making it easier for them to evaluate the attributes of the beef. Even if the negative attitudes formed after the contamination was discovered, we can conclude that the impact of discovering contaminated beef was small for beef produced far from Fukushima (areas not directly affected by radioactivity).

Although about 80% of the respondents showed aversion to “untested” Fukushima beef, this figure dropped to about 30% for “below the limit” Fukushima beef. This suggests that testing for radioactive material plays a role in ensuring demand for Fukushima beef. However, the choice experiment results suggest that describing additional details of radioactive material tests on the label generally does not help reduce consumer anxiety about Fukushima beef (Table 6). Furthermore, the results of the choice experiment analysis in Scenario 2 have elucidated the following points. The coefficient of “below one-tenth of the limit” is not significantly different from 0. This implies that being “below one-tenth of the limit” is considered the same as being “below the limit” from the viewpoint of easing consumer anxiety. Although the limit of radioactive material per kilogram of beef was revised from 500 to 100 becquerel in October 2012, this result suggests that consumers probably experience very little benefit from this revision. However, the “undetected” dummy variable had a significantly positive coefficient, indicating that consumers deem it helpful in reducing anxiety. As Ujiie (2011a, 2011b) argued, we can conclude that detailing the status of radioactive material tests on the label could possibly decrease consumer anxiety about food safety. However, dividing the test status into three levels causes consumers to differentiate among beef products, even though all three levels of beef produced in Fukushima meet the safety standard for consumption. This implies that “below the limit” and “below one-tenth of the limit” Fukushima beef could be rated relatively low by consumers, thus reducing its demand to the detriment of cattle farmers. Therefore, if the government were to mandate food labels with more specific test status, it is advisable to track changes in the market price of beef before and after such implementation. It would be necessary to examine, as accurately as possible, whether such changes cause losses to farmers and to compensate them accordingly.

We used Kagoshima beef as a competitor to Fukushima beef and differentiated Scenarios 1 and 2 by changing the rules for the labeling status for testing radioactive materials (Table 1). This resulted in a general relative increase in consumer valuation of Kagoshima beef: WTP per 100 g for “untested” Kagoshima beef significantly increased in Scenario 2 (JPY 664) compared to Scenario 1 (JPY 515); WTP per 100 g for “undetected” Kagoshima beef in Scenario 2 (JPY 760) was significantly higher than that for “below the limit” Kagoshima beef in Scenario 1 (JPY 618). WTP per 100 g for “untested” Kagoshima beef in Scenario 2 was significantly higher than those for all three types of Fukushima beef in Scenario 2 (JPY 433 to 553).

The following factors could have caused the abovementioned relationships. The majority of respondents had no concerns about radioactive contamination of Kagoshima beef, and the tightened test criteria by Kagoshima Prefecture reinforced this belief: beliefs about attributes of a product are one of the constructs that determine consumer attitude toward the product (Fishbein & Ajzen, 1975). About 77% of respondents showed no aversion to “untested” Kagoshima beef (Table 3); they trusted it would not have been contaminated. This is because the difference between their WTP for “untested” and “below the limit” Kagoshima beef was not significant (Table 8). For those without concerns about radioactive contamination of Kagoshima beef, the “undetected” criterion introduced for the Kagoshima beef in Scenario 2 also objectively proved their belief that “there is no risk of radioactive contamination to Kagoshima beef.” Although the standard “undetected” applies only to the tested Kagoshima beef, it could further reinforce consumer belief about the *overall* brand of Kagoshima beef; the rating of an overall brand is influenced by the rating of its highest-rated product (Aker, 1991), “undetected” Kagoshima beef. Therefore, it is conceivable that the tendency to choose Kagoshima beef increased because the majority of the respondents improved their belief in the overall Kagoshima beef brand.

From what has been discussed above, we can conclude that the benefit of a measure taken for the affected area may be diluted when a non-affected area employs the same measure. Thus, a situation could be created wherein losses in the affected area cannot be quickly reduced/recovered as other production areas adopt measures in their own interest. When a tremendous impact of the type seen here occurs in limited regions, resolving the issue may take long if we rely on individual production areas to voluntarily address it. Preferably, the central government should have adjusted the voluntary measures taken by each production area for a specified period after the accident.

We treated the respondents’ aversion to purchase beef produced in the studied prefectures based on the status of radioactive material tests as the dependent (endogenous) variable and exogenous variable in the ordered probit analysis and the choice experimental analysis, respectively. Therefore, an endogeneity bias in the estimates is possible (see Note 3). Because a small number of respondents were divided between two separate questionnaire scenarios, it was impossible to apply flexible discrete choice models to estimate the heterogeneity of preferences among respondents. However, our results are nevertheless meaningful, because this is the first study to econometrically demonstrate Japanese consumers’ valuation of domestic beef from both affected and non-affected areas based on test status for radioactive material.

Notes

(1) On April 1, 2012, the government further reduced the permissive dose for some foods to 1 mSv per year. The revised limit for rice and beef came into effect on October 1, 2012.

(2) However, local shipping organizations and distributors test the beef produced in Kagoshima for radioactive materials.

(3) One way to handle this issue is to follow the approach suggested by Ding, Veeman, & Adamowicz (2012). We may estimate the ECMNL model using the predicted values for the dummy variables

related to the purchase intention according to the status of radioactive material tests included in Equations (3) and (4). However, some dummy variables were predicted to be 0 for all respondents (Greene & Hensher, 2010). Therefore, it was impossible to use the predicted values for estimating our ECMNL model.

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Appendix A. Questions to gauge consumers' aversions to purchasing Fukushima and Kagoshima beef and definitions of the ordered categorical variables Y_f and Y_k

Listed below are six categories of beef for *yakiniku* (grilling). Please select the option most appropriate for you for each category. All the categories are *Wagyu* breeds.

		Options			
		1	2	3	4
	Categories of beef	I would purchase beef even if it is comparatively expensive	I would purchase beef if its price is reasonable	I would purchase beef if it is comparatively cheap	I would not purchase beef even if it is cheap
A.	Fukushima beef not tested for radioactive materials	○	○	○	○
B.	Fukushima beef with radioactive materials below the limit	○	○	○	○
C.	Fukushima beef without detectable radioactive materials	○	○	○	○
D.	Kagoshima beef not tested for radioactive materials	○	○	○	○
E.	Kagoshima beef with radioactive materials below the limit	○	○	○	○
F.	Kagoshima beef without detectable radioactive materials	○	○	○	○

Definition of Y_f

If respondent *i* selects

- Any option other than 4 for categories A–C, then $Y_{fi} = 0$.
- Option 4 for category A and any option other than 4 for categories B and C, then $Y_{fi} = 1$.
- Option 4 for categories A and B and any option other than 4 for category C, then $Y_{fi} = 2$.
- Option 4 for all categories A–C, then $Y_{fi} = 3$.

Definition of Y_k

If respondent *i* selects

- Any option other than 4 for categories D–F, then $Y_{ki} = 0$.
- Option 4 for category D and any option other than 4 for categories E and F, then $Y_{ki} = 1$.
- Option 4 for categories D and E and any option other than 4 for category F, then $Y_{ki} = 2$.
- Option 4 for all categories D–F, then $Y_{ki} = 3$.

Appendix B. Result of factor analysis assessing respondents' knowledge of and attitudes on radioactive contamination of food

A factor analysis was conducted to extract the respondents' knowledge of and attitudes on radioactive contamination of food from the responses to questions about 13 items concerning this problem. Respondents rated these items on a 7-point scale, where 1 means "I completely disagree/I have never heard of it" and 7 means "I completely agree/I have certainly heard of it." SPSS 12.0 (SPSS Inc., Chicago, IL, USA) with a principal factor method with promax rotation was used for the analysis. The interpretation of each of the extracted factors was based on factor loadings ≥ 0.50.

The factor analysis of these statements extracted 3 factors as shown in the following table. The first of the three factors is highly correlated with reliability about the information related to radioactive contamination of food items provided by mass media, experts, and the government. This factor is labeled as *confidence in the information about radioactive contamination of food* (*FSI*). The second factor, labeled as *knowledge on radioactive material and countermeasures against its spread in the food supply* (*FSK*), is strongly associated with the knowledge about radioactive material and countermeasures against its spread in the food chain. Finally, the third factor is highly correlated with consumer confidence in the limit of radioactive materials in food- and shipment-related regulations mandated by the government, and it is positively associated with consumer trust in the efforts of the farmers to produce safe agricultural and livestock products. This factor is labeled *confidence in the actions taken by the government and producers* (*FST*).

Factor loading matrix after promax rotation (*N* = 392).

	Factor 1	Factor 2	Factor 3
TV reports* are reliable	**0.96**	−0.01	−0.05
Newspaper reports* are reliable	**0.96**	−0.01	−0.05
Information* provided by experts is reliable	**0.69**	−0.02	0.08
Information* published by the government is reliable	**0.58**	0.05	0.28
Following the Fukushima accident, the government promptly established limits for radioactive materials in food items	0.03	**0.70**	−0.24
Even if cattle have ingested radioactive materials, providing them with clean feed will gradually decrease these materials inside their bodies	0.02	**0.69**	0.12
Occasional consumption of food items that exceed the limit poses no health risks	−0.03	**0.66**	0.11
Since radioiodine has a short half-life, limits have not been established for radioiodine in meat for consumption	−0.08	**0.63**	0.19
Different types of radiation have different effects on the human body	0.03	**0.61**	−0.20
Some local governments are voluntarily testing food items other than those they are mandated to test for radioactive contamination	0.01	**0.58**	0.01
Tested food items containing radioactive materials below the limit are safe for consumption	−0.04	−0.03	**0.84**
Food items available on the market after being tested for radioactive materials and subject to government countermeasures are safe	0.09	0.00	**0.81**
Farmers take adequate care to provide safe agricultural and livestock products	0.13	0.05	**0.50**

Notes: * implies that all reports/information refer to radioactive contamination of food items. Factor loadings are from factor pattern coefficients. Factor loadings ≥ 0.50 appear in bold.