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# Meat the challenge: Segmentation and profiling of Japanese beef mince and its substitutes consumers

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ABSTRACT

Shifts in protein production methods are an emerging challenge toward realizing a sustainable society. This paper aims to examine preferences among Japanese consumers regarding attributes of beef mince and its substitutes, to develop consumer segments based on these preferences, and to explore the segment with higher acceptance of replacement from conventional products. This paper also aims to explain intersegment differences from consumer heterogeneity in human values, scientific literacy, and sociodemographic viewpoints for a deeper understanding of consumer behavior in each segment. The results of an online choice experiment involving 4421 consumers in Japan, using food labels on mince showed that Japanese-origin organic beef was associated with the highest utility among the five production methods mentioned. Five consumer segments were identified with latent class analysis: *novelty accepters*, *generous customers*, *attribute-economy balancers*, *price–conscious*, and *conservatives*, which vary in preference in choice behavior, sociodemographic, human values, and scientific literacy.

## 1. Introduction

Meat has continued to be the primary source of protein for much of the world's population (Salter, 2018). Its overall consumption has increased along with the ever-growing population to date (Godfray et al., 2018). With the global population expected to continue to increase with urbanization, particularly in emerging economies where population growth and purchasing power are the most pronounced, there is an urgent global need to anticipate and meet the demand (Stoll-Kleemann & O'Riordan, 2015). In Japan, beef consumption increased with economic growth after World War II and the rise in national income (Lee et al., 2013). The importance of livestock farming as an industry has also grown, and Wagyu beef has come to be positioned as one of the most important agricultural export items today (Ministry of Agriculture Forestry and Fisheries of Japan, 2021).

On the other hand, livestock production, traditionally the primary supply method of meat, is at a significant turning point. It is increasingly criticized for its enormous environmental impact, as it is considered a major source of greenhouse gas emissions that contribute to global warming (Allen & Hof, 2019; Gomez-Zavaglia, Mejuto, & Simal-Gandara, 2020), requires large areas of farmland to produce feed (Ellis, Goldewijk, Siebert, Lightman, & Ramankutty, 2010), and threatens water security (Gomez-Zavaglia et al., 2020). Improving animal welfare has become a significant issue worldwide (Buller, Blokhuis, Jensen, & Keeling, 2018). To address the challenges and increase the sustainability of livestock production, ongoing efforts are to encourage a shift to organic livestock production using pasture and organic feed, (Escribano, 2016) as well as livestock production that improves animal welfare (Balzani & Hanlon, 2020). In addition, to reduce meat consumption, efforts are underway to use meat substitutes produced from plant–based materials (Michel, Hartmann, & Siegrist, 2021) and artificially cultured cells (Post, 2014) as protein.

Various studies have been conducted in search of more sustainable production methods and meat substitutes from various perspectives, for instance, environmental impact based on life-cycle assessment (Tsutsumi, Ono, Ogasawara, & Hojito, 2016), consumer acceptance (Palmieri, Perito, & Lupi, 2021), scalability for mass production (Hayek & Garrett, 2018), and profitability (Ahmed et al., 2021). However, it is difficult to generalize regarding the optimal production method, as each has its advantages and disadvantages, and their trade-offs have been pointed out. Given this current situation, in the short term, it is important to envision a market in which meat and its alternatives from multiple production systems exist in parallel and are supplied to consumers who accept each of them to achieve a real shift in production. To this

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end, it is necessary to forecast the composition of the market shortly.

Among various factors influencing on meat consumption, extrinsic product attributes are considered a major design space in consumer communication, and several studies have attempted to measure the impact of such information on consumers preferences in quantity, such as willingness to pay (Carlsson, Frykblom, & Lagerkvist, 2007; Dudinskaya et al., 2021; Grasso, Rondoni, Bari, Smith, & Mansilla, 2022; Katare, Yim, Byrne, Wang, & Wetzstein, 2021; Miranda-de la Lama et al., 2017; Napolitano et al., 2010; Ortega, Hong, Wang, & Wu, 2016; Zanoli et al., 2013). Using conventional meat products as a reference, consumers were favorable toward price premium for sustainable farm-grown meat such as that produced by organic and animal-welfare friendly farming: for example, 3.26 to 3.46 SEK/kg for the use of mobile abattoir (Carlsson et al., 2007), 23.410 RMB/500 g for animal welfare labeling and 25.138 RMB/kg for organic labeling (Ortega et al., 2016), 21.88 EUR/kg for organic labeling and 5.29 EUR/kg for animal welfare labeling (Zanoli et al., 2013). On the other hand, it was suggested that plant-based substitutes receive negative price premiums when compared with farm–raised meat: for example, −14.2% of price premium when it was informed as a plant-based substitute (Grasso et al., 2022), and − 0.038 to −0.382 USD/6 oz. for plant-based substitute (Katare et al., 2021). Cultured meat has been reported to receive price premiums over conventional meats: for example, +1.10 to +1.66 USD for beef patty (Kantor & Kantor, 2021), +2% compared to conventional meat (Zhang, Li, & Bai, 2020), although the gap between willingness to taste and to purchase was also noted. That said, several studies suggested the presence of heterogeneity in consumer preference or the existence of a small niche group among the consumers (Carlsson et al., 2007; Dudinskaya et al., 2021; Koistinen et al., 2013; Ortega et al., 2016). Thus, envisioning several production methods coexisting on the market, there is a need for research on acceptance and preferences among Japanese consumers regarding meat and meat substitutes using segmentation to consider consumer heterogeneity, which leads to the establishment of optimal consumer communication.

This paper aims to examine Japanese consumers' preferences regarding attributes of beef mince and its substitutes using product labeling, to develop consumer segments based on these preferences, and to explore the segment with higher acceptance of replacement from conventional products. We placed organic and animal-welfare friendly as more sustainable beef mince than conventional products, and plant–based and cultured meat as meat substitutes contributing to the reduction of meat production. This paper also aims to explain inter-segment differences from viewpoints of consumer' heterogeneity regarding human values, scientific literacy, and sociodemographic for a deeper understanding of consumer behavior in each segment.

## 2. Material and methods

### 2.1. Data collection

We conducted an Internet-based questionnaire through a monitor recruiting company in Japan. The survey was conducted March 26–28, 2020, following a preliminary survey to confirm the questionnaire items in the choice experiment. Respondents who consumed beef and were the main shopper of beef in the household were eligible to participate. A total of 5562 samples were collected, and 4421 were analyzed after removing samples containing a blank answer for household income. The sociodemographic composition of the respondents is summarized in Table 1. We justified the sample size of 4421 based on the two aspects of representativeness of the population and empirical reference of eligibility for latent class analysis. First, the sample number is justified from the population size. In the current study, although the number of the beef shoppers in Japan may not be defined clearly, it cannot exceed the maximum of around 120,000,000, which is the population of Japan. Yamane's equation (Yamane, 1967) is commonly used to simply calculate a required sample size $n$ from population $N$ and the acceptable sampling error $e$. When $N = 120000000$, $e = 0.05$ (95% confidence level),

$$n = \frac{N}{1 + Ne^2} = 399.999 < 4421 \quad (1)$$

Second, the sample size can be justified with the eligibility for the analysis method applied. In a latent class model, a sample size of 300 or more is suggested as acceptable (Nylund-Gibson & Choi, 2018), although "more is better, but it depends" as with other kinds of structural equation modeling (Weller, Bowen, & Faubert, 2020).

To protect the participants, consent regarding participation in the survey was obtained at the start of the questionnaire, and only those who agreed were able to continue. All the data was anonymized before it was handed to us by the monitor recruiting company. The data has been processed and analyzed following guidance from the Human Subject Research Ethics Review Committee at Tokyo Institute of Technology.

**Table 1**
Sociodemographic characteristics of respondents ($N = 4421$).

| | | N | % |
|---|---|---|---|
| Gender | Male | 1949 | 44.1 |
| | Female | 2472 | 55.9 |
| Age | Average [years old] | 46.3 | |
| | 20–39 | 1371 | 31.0 |
| | 40–59 | 2349 | 53.1 |
| | 60+ | 701 | 15.9 |
| Household Income | Under 4 million JPY | 1073 | 20.2 |
| | 4 to 6 million JPY | 1976 | 37.1 |
| | Over 6 million JPY | 1805 | 33.9 |
| | Unknown | 467 | 8.8 |
| Single–person household | Yes | 601 | 13.6 |
| | No | 3820 | 86.4 |
| Under 18 in household | Yes | 2880 | 65.1 |
| | No | 1541 | 34.9 |
| Full-time homemaker | Yes | 867 | 19.6 |
| | No | 3554 | 80.4 |
| Education | Primary and Secondary | 1249 | 28.3 |
| | Vocational | 1207 | 27.3 |
| | Undergraduate | 1776 | 40.2 |
| | Postgraduate | 189 | 4.3 |

### 2.2. Choice experiment

Choice experiments were used to estimate consumer preferences by reproducing actual purchasing situations. Furthermore, they can be used in experiments that assume hypothetical purchases of products and attributes that are not yet common in the real market environment (Louviere, Hensher, Swait, & Adamowicz, 2000). A choice experiment was thus suitable for this research involving unfamiliar production methods among Japanese consumers, such as animal–friendly beef and cultured meat.

The three product attributes used in the choice experiment we conducted were as follows: the price per unit quantity and the country of origin, which are important items for Japanese consumers when purchasing beef (Japan Meat Information Service Center, 2018), and the production method label. In addition to the standard conventional livestock production method, four levels of production were set: organic livestock, animal welfare friendly, meat substituted with plant materials, and cultured meat. The price per unit volume was set at five levels, 100, 300, 500, 700, and 900 JPY per 100 g, in reference to the price of beef mince at supermarkets and mail order sites. For country–of–origin labeling, five levels were set: Australia, U.S.A., New Zealand, and Canada, in descending order of imported volume (Ministry of Finance of Japan, 2019), in addition to Japan (domestic). Question items were designed using orthogonal design with R 3.6.2 (R Core Team, 2020) and Doe.base package (Grömping, 2018). This experiment had five attributes, each with five levels. Twenty–five labels were created with one level for each of the three attributes, and each label appeared twice

equally often.

Respondents were presented an image of the product and read a description of the meanings of each production method on the labels, and then selected one of the two labels or the opt–out option of not buying either, doing this 25 times for different combinations of labels (Fig. 1).

### 2.3. Portrait value questionnaire for human values

Human values have been reported to be an important consumers' attribute influence food choice behavior (Aertsens, Verbeke, Mondelaers, & van Huylenbroeck, 2009). Schwartz proposed ten basic human values guiding an individual's behavior (Schwartz, 1992). The ten values are arranged in a circle based on the opposing higher values. Conservation (security, conformity, and tradition), for instance, opposes openness to change (stimulation, self–direction, and hedonism), and self–enhancement (hedonism, achievement, and power) opposes self–transcendence (benevolence and universalism). The PVQ–21 scale, consisting of 21 questions on a 6–point scale, was proposed (Davidov, Schmidt, & Schwartz, 2008; Schwartz, 2006) and adapted for the current study.

### 2.4. Kawamoto's short scientific literacy survey

Scientific literacy has been considered to influence consumers' choice behavior (Charlebois, Somogyi, Music, & Cunningham, 2019; Richards-Kortum, Buckley, Schwarz, Atkinson, & Follen, 2007). To enhance science communication, Kawamoto developed a scale that includes three aspects: knowledge of science and technology (scientific factor), interest in society (social factor), and attitude toward science and technology (science-appreciating factor). These aspects are used to classify individuals into four groups: *inquisitive type* (people with greater scientific knowledge, scientific and social interests, and appreciation of science), *sciencephiles* (greater science knowledge but less interest in social fields), *life-centered type* (greater social interest and relatively less science knowledge), and *low-interest type* (less interest in both science and social fields) (Kawamoto, Nakayama, & Saijo, 2013a). Kawamoto intended to cluster citizens into four groups to support optimal communication design according to their characteristics (Kawamoto et al., 2013a). The membership share of a cluster would indicate consumers' tendencies toward scientific literacy in a group (Kawamoto, Nakayama, & Saijo, 2013b). For measurement, a scale consisting of ten questions on a 4-point scale was proposed (Kawamoto et al., 2013b) and adapted for the current study.

## 3. Statistical analysis

Statistical analysis was conducted with R 4.0.3 (R Core Team, 2020). Details are provided as follows. First, we analyzed data collected from our choice experiment with a multinominal logit model to examine the utility of each attribute regarding choice behavior. Second, we analyzed the data using latent class analysis, with the hypothesis of existing heterogeneity in preferences. Each individual was sorted into a number of segments (latent class). Third, we tested the intersegment in sociodemographic, human values (Schwartz), and scientific literacy (Kawamoto) to observe differences in consumers' attributes among the segments.

The latent model hypothesized in the present work is relatively simpler because the segments are determined purely on the basis of the attributes of the meat and its substitutes (i.e., production method, origin, and price). This model allowed us to focus on the segment observation based on product attributes that can be designed and manipulated, whereas the personal values of the consumers will be given conditions for marketers. We considered that the segmentation results based on manipulatable product attributes should be more beneficial for the readers than complex model results in terms of future marketing applications. It also contributes to the reduction of computing power required for the calculation (especially with a large number of samples, such as the set analyzed in the present work). Our model can be extended in the future by introducing different measures while keeping the same segment structures. There should be measures to characterize consumers other than those applied in the current paper. Once the segment structure, has been found, the difference between segments can be easily compared according to the nature of the measure, such as whether it is a categorical or numerical scale.



| Production method | Description |
|---|---|
| Conventional | Meat raised using currently prevailing methods of beef cattle production |
| Organic | Meat raised using organic farming methods, from feed to Organic JAS-certified beef |
| AW friendly | Animal-welfare friendly raised and with a higher standard of control over the physical and mental condition of the beef cattle |
| Plant based | Foods that resemble meat in appearance and flavor by processing legumes and adding seasonings |
| Cultured | Meat produced by artificially culturing muscle cells from beef cattle |

Product with which label do you want to purchase?

| | |
|---|---|
| **Production method:** | Organic |
| **Country of origin:** | Canada |
| **Price (JPY per 100g):** | 700 |

| | |
|---|---|
| **Production method:** | AW friendly |
| **Country of origin:** | Canada |
| **Price (JPY per 100g):** | 900 |

○ 1
● 2
○ None of above

**Fig. 1.** Experiment screen presented to the respondents.

### 3.1. Multinominal logit model

McFadden states that in random utility theory, individual choice is based on the magnitude of utility. The utility $U$ of individual $n$ at choice opportunity $t$ is expressed in two parts: a fixed term (observed utility) and an error (random utility) term (McFadden, 2001).

$$U_{int} = V_{int} + e_{int} \tag{2}$$

Lancaster described the observed utility $V_i$ of alternative $i$ as the sum of the group of attributes $X$ describing alternative $i$ and $\beta$, the parameters associated with the various levels of specific attributes (Lancaster, 1966).

$$V_i = \beta_0 + \sum_{k=1}^{K} \beta_k X_k \tag{3}$$

When alternative $i$ is chosen over competing alternative $j$, associated utility $U_i$ should be $U_i > U_j$. Alternative $i$'s observed utility can be assumed as the linear function below consisting of production method (method), country of origin (origin), and price per a hundred gram (price).

$$V_i = ASC_i + \beta_{method} Method_i + \beta_{origin} Origin_i + \beta_{price} Price_i \tag{4}$$

The probability of choosing alternative $i$ is given by

$$Prob_{int} = \frac{exp(\beta X_{int})}{\sum_{i=1}^{I} exp(\beta X_{int})} \tag{5}$$

### 3.2. Latent class analysis

The advantage of the latent class model is that it captures heterogeneity among respondents (Boxall & Adamowicz, 2002) while multinominal logit model has its limitation of ineligibility in it. This is done by assuming $S$ segments between respondents. Each segment $s$ is distinct and has a different $\beta$. In this model, the probability that respondent $n$ from segment $s$ chooses choice $i$ is given by the equation below, where $\beta'_s$ is a segment–specific parameter, as $t(n)$ choice opportunity in $T(n)$ sets

$$Prob_{ins} = \prod_{t(n)}^{T(n)} \frac{exp(\beta_s' X_{int})}{\sum_{i=1}^{I} exp(\beta_s' X_{int})} \tag{6}$$

One of the features of the latent class model is estimation of class probability values $H_{ns}$, which enables estimations of the probability of falling into different segments for each respondent.

$$Prob_{ns} = \sum_{s=1}^{S} Prob_{ins} H_{ns} \tag{7}$$

### 3.3. Scoring and clustering on scientific literacy

#### 3.3.1. Exploratory factor analysis

To extract factors from responses, an exploratory factor analysis with a maximum likelihood method and an oblique goemin rotation was performed on the ten items obtained from scientific literacy questions. Factor scores for each factor were calculated with Thurstone's regression method (William, 2022). Calculated scores were used for the cluster analysis in the next step.

#### 3.3.2. K–means clustering

To allocate each respondent to one of the four clusters (*inquisitive type*, *sciencephiles*, *life–centered*, and *low–interest*), k–means clustering was performed. Following the scale inventors' method (Kawamoto et al., 2013a), respondents were distributed into four clusters.

### 3.4. Intersegment comparison

Intersegment comparison was conducted from the viewpoints of human values, scientific literacy, and sociodemographic variables. Human values scores were calculated according to the recommended method by the inventor of the scale (Schwartz, 2014). A one–way analysis of variance (one–way ANOVA) was performed on ten human values scores over classes. Chi–square tests of independence were performed to assess the difference in the membership share of scientific literacy clusters and sociodemographic between segments.

## 4. Results

In the following, we present the results from each statistical analysis.

### 4.1. An overview of Japanese meat and its substitutes market

The results from the estimation with the multinominal logit model are presented in Table 2. To examine consumer preferences for attribute levels, utility values can be compared within the attributes. The higher the utility associated with a particular attribute level, the more valuable that level is to the respondents. For production methods, organic label is the only level associated with higher–than–conventional method and the highest value among all the production methods, followed by animal welfare friendly. Meat substitutes of plant–based and cultured labels were associated with less value than real meat. Regarding country of origin, imported product labels were associated with lower utility than made in Japan. Among foreign country labels, Australia was associated with the highest utility, followed by the United States. Thus, if we consider the Japanese market as homogeneous, consumers prefer organic beef produced domestically (in Japan). Other production methods of animal–welfare friendly, plant–based, and cultured were less preferred than conventionally produced product (baseline).

### 4.2. Market segmentation

We conducted latent class analysis to segment the respondents according to their preferences for the product attributes influencing the product choice. The optimal segment number was identified by referring to the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and the researcher's own judgments (Hess & Palma, 2019). We examined models with two to six segments. Table A1 summarizes the values of loglikelihood which suggested improving goodness–of–fit as the number of the segments increased, and the two information criteria. Both AIC and BIC had the smallest values with five segments, suggesting the best fit in our examination.

Table A2 shows the estimated utility level for each segment. Most utility level values were statistically significant at the 99% level. Five segments were identified and named according to the respondents' choice preferences in each segment: *novelty accepters*, *generous customers*, *attribute–economy balancers*, *price–conscious*, and *conservatives*.

**Table 2**
Results of multinominal logit model ($N = 4421$).

| Attribute | Level | Coefficient | | Std. Err. |
|---|---|---|---|---|
| ASC | | 1.378 | *** | 0.101 |
| Production method | Organic | 0.110 | *** | 0.048 |
| | Animal–welfare friendly | −0.251 | *** | 0.053 |
| | Plant–based | −0.467 | *** | 0.076 |
| | Cultured | −0.964 | *** | 0.092 |
| Country of Origin | Australia | −0.741 | *** | 0.074 |
| | United States | −0.818 | *** | 0.082 |
| | New Zealand | −0.949 | *** | 0.072 |
| | Canada | −0.802 | *** | 0.068 |
| Price | | −0.002 | *** | 0.000 |

Reference levels are conventional method for production method and Japan for country of origin. ASC represents the alternative–specific constant value.
Price is a numeric variable.
Significance codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05.

The first segment associated all the production method labels with higher utility than the conventional method, whereas the other segments associated meat substitute labels with lower utility than the latter. This segment formed by 12.8% of the respondents was named *novelty accepters*, as it refers to a group of consumers who accept novel products at an earlier point in market introduction, although this segment had the smallest population among the five. Understanding this group's decision–making and purchasing behavior, considering that it also associates alternative production method labels with higher utility, would contribute to the development of measures to promote more sustainable options.

The largest segment, *generous customers* comprising 31.9% of the respondents, also associated the organic and domestic label with the highest utility, characterized by low price sensitivity to the production method and country of origin. Choice behavior of this segment is such that they are willing to pay more for what they want. Organic/animal–welfare friendly beef production, tends to be more expensive than conventional production. Meat substitutes could face the problem of scaling for economy in production, and there is no guarantee that they would be cheaper alternatives to conventionally produced meats (Rubio, Xiang, & Kaplan, 2020). Communication to this segment of consumers is expected to emphasize the value of purchasing and consuming products, such as contribution to health, reduction of environmental impact, and protection of the domestic livestock industry, rather than price comparisons.

The third segment is the *attribute–economy balancers*, a group of consumers who share with generous customers the highest utility associated with organic and domestic labels, but their price sensitivity is standard. Consumers in this segment are considered to have a choice behavior whereby they want to purchase products with better properties such as domestic and organic, while doing so within budget constraints. In order to appeal to this segment of consumers, communication that encourages them to make a purchase should be conducted by offering them special consumption opportunities.

We named the fourth segment *price–conscious* as it also associated the greatest utility with organic and domestic labels, but price sensitivity characterized this segment most strongly. In convincing this segment of consumers to shift from conventional products, the price would be key in communication. Although it is considered challenging to lower the production cost of organic beef products compared with conventional products, this segment of consumers would be attracted when organic beef production becomes more popular in Japan and the scale of economy would leverage the cost reduction in feeding or credential certification processes.

The last segment was named *conservatives*, as it was the only one of the five segments to associate the organic label with a lower utility for conventional production methods, whereas beef produced by conventional methods was associated with the highest utility. Thus, consumers in this segment can be considered as not receptive to meat produced by alternative production methods and its substitutes. The contrast with *novelty accepters* is appropriate for examining the factors involved in the acceptance of alternative production methods.

Willingness to pay for each level of attributes was calculated for each class and multinominal logit model and presented in Table 3 in form of price premium from reference levels; Reference levels are conventional method for production method and Japan for country of origin.

### 4.3. Intersegment comparison

#### 4.3.1. Intersegment comparison from human values perspective

To compare the difference between segments in human values, one–way ANOVA was performed on ten human value scores over segments. With tradition ($df = 4, F = 1.112, p = 0.349$) being an exception, there were statistically significant differences in mean values scores on nine values out of ten; security ($df = 4, F = 5.949, p < 0.001$), conformity ($df = 4, F = 9.436, p < 0.001$), benevolence ($df = 4, F = 3.827, p < 0.001$), universalism ($df = 4, F = 7.7365, p < 0.001$), self–direction ($df = 4, F = 5.090, p < 0.001$), stimulation ($df = 4, F = 24.517, p < 0.001$), hedonism ($df = 4, F = 4.889, p < 0.001$), achievement ($df = 4, F = 5.205, p < 0.001$), and power($df = 4, F = 8.662, p < 0.001$). Table 4 presents the mean human values scores of each segment and the results of Scheffe's Test for multiple comparisons conducted as a post–hoc test.

#### 4.3.2. Intersegment comparison from scientific literacy perspective

Exploratory factor analysis was performed to extract three factors from the responses to 10 questions. The factors were named as originally proposed (Kawamoto et al., 2013a). The results are shown in Table A3. For each factor, factor scores were calculated with Thurstone's regression method. Then, on the basis of the calculated factor scores, respondents were allocated into four clusters with *k*-means clustering (Table A4). The clusters were named on the basis of their center, as originally proposed (Kawamoto et al., 2013a).

A chi-square test of independence was performed to assess the difference in the membership share of the scientific literacy cluster among segments. The membership share of the consumer cluster would indicate the consumers' tendency toward scientific literacy. Statistically significant differences were found regarding the scientific literacy cluster membership share (Table 5).

**Table 3**
Willingness to pay for attribute levels.

| | | All | | Novelty accepters | | Generous customers | | Attribute–economy balancers | | Price–conscious | | Conservatives | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Attribute | Level | $N = 4421$, 100% | | $N = 566$, 12.8% | | $N = 1412$, 31.9% | | $N = 810$, 18.3% | | $N = 798$, 18.1% | | $N = 835$, 18.9% | |
| Production method | Organic | 55.00 | *** | 251.18 | *** | 428.08 | *** | 178.46 | *** | 43.59 | *** | −61.90 | *** |
| | Animal–welfare friendly | −125.50 | *** | 228.10 | *** | −1768.95 | *** | −155.91 | *** | 8.32 | | −250.09 | *** |
| | Plant–based | −233.50 | *** | 261.02 | *** | −3941.48 | *** | −378.42 | *** | −25.56 | * | −501.20 | *** |
| | Cultured | −482.00 | *** | 184.99 | *** | −9010.44 | *** | −555.29 | *** | −187.69 | *** | −970.93 | *** |
| Country of Origin | Australia | −370.50 | *** | 114.18 | *** | −1928.46 | *** | −1268.65 | *** | −16.88 | * | −324.09 | *** |
| | United States | −409.00 | *** | 4.23 | | −2651.41 | *** | −1274.75 | *** | −63.14 | *** | −342.25 | *** |
| | New Zealand | −474.50 | *** | −288.03 | *** | −2323.15 | *** | −902.94 | *** | −81.53 | *** | −295.40 | *** |
| | Canada | −401.00 | *** | −60.24 | *** | −2242.45 | *** | −883.55 | *** | −47.11 | *** | −251.24 | *** |

Reference levels are conventional method for production method and Japan for country of origin.
Unit is Japanese yen.
Significance codes: $0 < *** < 0.001 < ** < 0.01 < * < 0.05$.
Willingness to pay: $WTP_{k|s} = -\left(\frac{\beta_{k|s}}{\beta_{price|s.}}\right)$.
All donates multinominal logit model.

**Table 4**
Results of Scheffe's Test on human values.

| | All | | Novelty accepters | | | Generous customers | | | Attribute–economy balancers | | | Price–conscious | | | Conservatives | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $N = 4421$, 100% | | $N = 566$, 12.8% | | | $N = 1412$, 31.9% | | | $N = 810$, 18.3% | | | $N = 798$, 18.1% | | | $N = 835$, 18.9% | | |
| | Mean | S.D. | Mean | | S.D. | Mean | | S.D. | Mean | | S.D. | Mean | | S.D. | Mean | | S.D. |
| Security | 0.348 | 0.703 | 0.255 | c | 0.720 | 0.319 | bc | 0.668 | 0.347 | abc | 0.707 | 0.399 | ab | 0.710 | 0.414 | a | 0.732 |
| Conformity | 0.031 | 0.663 | −0.012 | c | 0.656 | −0.027 | c | 0.665 | 0.105 | ab | 0.634 | 0.116 | a | 0.685 | 0.007 | bc | 0.655 |
| Tradition | −0.079 | 0.691 | −0.094 | N. A. | 0.727 | −0.103 | N. A. | 0.689 | −0.044 | N. A. | 0.661 | −0.062 | N. A. | 0.672 | −0.081 | N. A. | 0.702 |
| Benevolence | 0.222 | 0.630 | 0.137 | b | 0.667 | 0.227 | ab | 0.623 | 0.241 | ab | 0.629 | 0.210 | ab | 0.628 | 0.265 | a | 0.617 |
| Universalism | 0.219 | 0.546 | 0.115 | b | 0.569 | 0.203 | a | 0.561 | 0.252 | a | 0.497 | 0.260 | a | 0.537 | 0.244 | a | 0.550 |
| Self–direction | 0.136 | 0.687 | 0.106 | ab | 0.679 | 0.168 | a | 0.681 | 0.072 | b | 0.665 | 0.201 | a | 0.717 | 0.103 | ab | 0.690 |
| Stimulation | −0.589 | 0.837 | −0.408 | a | 0.849 | −0.485 | a | 0.806 | −0.685 | bc | 0.842 | −0.764 | c | 0.840 | −0.630 | b | 0.829 |
| Hedonism | 0.298 | 0.688 | 0.304 | ab | 0.712 | 0.246 | b | 0.679 | 0.275 | ab | 0.692 | 0.359 | a | 0.701 | 0.346 | a | 0.661 |
| Achievement | −0.318 | 0.786 | −0.195 | a | 0.782 | −0.305 | ab | 0.795 | −0.340 | b | 0.758 | −0.381 | b | 0.777 | −0.342 | b | 0.800 |
| Power | −0.378 | 0.763 | −0.266 | a | 0.745 | −0.347 | ab | 0.756 | −0.348 | ab | 0.743 | −0.468 | b | 0.762 | −0.450 | c | 0.793 |

Different letters (descending order) indicate significant differences at $p < 0.05$.
N.A. donates "not analyzed."
All donates the summary of all 4421 samples.

**Table 5**
Results of chi–square test for scientific literacy.

| | All | | Novelty accepters | | Generous customers | | Attribute–economy balancers | | Price–conscious | | Conservatives | | Chi–square/p–value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $N = 4421$, 100% | | $N = 566$, 12.8% | | $N = 1412$, 31.9% | | $N = 810$, 18.3% | | $N = 798$, 18.1% | | $N = 835$, 18.9% | | |
| | N | % | N | % | N | % | N | % | N | % | N | % | |
| Inquisitive type | 1235 | 27.9 | 161 | 28.4 | 505 | 35.8 | 157 | 19.4 | 175 | 21.9 | 237 | 28.4 | 170.5 |
| Sciencephiles | 952 | 21.5 | 123 | 21.7 | 318 | 22.5 | 129 | 15.9 | 202 | 25.3 | 180 | 21.6 | $p < 0.001$ |
| Life–centered | 1134 | 25.7 | 153 | 27.0 | 336 | 23.8 | 285 | 35.2 | 172 | 21.6 | 188 | 22.5 | |
| Low–interested | 1100 | 24.9 | 129 | 22.8 | 253 | 17.9 | 239 | 29.5 | 249 | 31.2 | 230 | 27.5 | |

All donates the summary of all 4421 samples.

#### 4.3.3. *Intersegment comparison from sociodemographic perspective*

A chi–square test of independence was performed to assess the relationship between segment and sociodemographic. Statistically significant differences exist regarding gender, age, household income, whether the respondent is in a single–person household, the presence household members under 18 years old, whether the respondent is a full–time homemaker, and education background (Table 6).

## 5. Discussion

### 5.1. *Characteristics of Japanese beef and the beef substitutes market*

Based on the results for both the multinominal logit model and the latent class analysis across most of the five segments, domestically produced products were shown to be preferred to foreign products, which is consistent with the results of a previous report in Japan (Sonoda, Oishi, Chomei, & Hirooka, 2018). Previous studies from other countries also reported a positive effect of local production labels on willingness to pay for meat products. Zanoli et al. revealed that Italian consumers valued Italian or locally bred meat attribute ranging from 24.69 to 6.40 EUR/kg (Zanoli et al., 2013). Dudinskaya et al. revealed that European consumers presented high willingness to pay for meat of national origin over one from New Zealand or EU origin (Dudinskaya et al., 2021). Ortega et al. suggested that Chinese consumers preferred Australian label over domestic and U.S. for food safety concerns (Ortega et al., 2016). In Japan, Kim suggested that Japanese consumers tend to prefer products of domestic origin in reduction of food safety risks (Kim, 2008). Increasing domestic production is thus considered important for meeting consumer food safety needs.

The results showed that about 80% of the respondents considered organic beef label a better alternative than labels of conventional production methods. With the multi–nominal logit model, Japanese consumers were willing to pay the price premium of 55.00 JPY/100 g for organic label (The currency around the questionnaire period was 113.96 JPY = 1 USD, 123.93 JPY = 1 EUR.). Zanoli et al. reported that Italian consumers were willing to pay a price premium of 21.88 euros/kg, which is much higher than the premium observed in the current study (Zanoli et al., 2013). The results are hopeful in terms of promoting the shift to sustainably produced products, in that appropriate communication can promote value recognition and change choice behavior, even toward more expensive products.

Notably, animal–welfare–friendly labels were associated with lower utility than the conventional methods. Animal–welfare–friendly practices for beef cattle farms aimed at improving sustainability are not yet common among Japanese consumers. Consumer awareness of the farm animal welfare issue has been reported to be around 10%, which is considered relatively lower when compared with European countries (Washio, Ohashi, & Saijo, 2019, 2020). Moreover, the results of the current study suggest the replacement of beef meat with meat substitutes such as plant–based meat or cultured meat is difficult at this point, as the respondents associated them with lower utility than those with organic beef or animal–welfare–friendly beef labels. Negative preference toward plant–based substitutes in compared with farm–raised meat aligns the previous studies (Grasso et al., 2022; Katare et al., 2021). Psychological barriers to the acceptance of novel food, known as food neophobia, is one possible explanation, and has been reported to exist for meat produced in novel ways and meat substitutes (Hoek et al., 2011). Unfamiliarity of new product attributes can thus be an obstacle to consumer acceptance, and therefor that consumer communication such as information presentation (Zhang et al., 2020) and naming (Asioli, Bazzani, & Nayga, 2022) needs to be explored.

### 5.2. *Intersegment comparison and suggested market implications*

Five consumer segments were extracted from latent class analysis and then named according to their choice preferences: *novelty accepters*,

**Table 6**
Results of chi–square test for sociodemographic.

| | Novelty accepters | | Generous customers | | Attribute–economy balancers | | Price–conscious | | Conservatives | | Chi–square/p–value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | *N* | % | *N* | % | *N* | % | *N* | % | *N* | % | |
| Gender | | | | | | | | | | | |
| Male | 333 | 58.8 | 737 | 52.2 | 234 | 28.9 | 310 | 38.8 | 335 | 40.1 | 177.72 |
| Female | 233 | 41.2 | 675 | 47.8 | 576 | 71.1 | 488 | 61.2 | 500 | 59.9 | $p < 0.001$ |
| Age | | | | | | | | | | | |
| Average [years old] | 43.4 | | 46.1 | | 47.2 | | 47.2 | | 46.8 | | |
| 20–39 | 224 | 39.6 | 446 | 31.6 | 227 | 28.0 | 222 | 27.8 | 252 | 30.2 | 36.467 |
| 40–59 | 284 | 50.2 | 748 | 53.0 | 444 | 54.8 | 441 | 55.3 | 432 | 51.7 | $p < 0.001$ |
| 60+ | 58 | 10.2 | 218 | 15.4 | 139 | 17.2 | 135 | 16.9 | 151 | 18.1 | |
| Household Income | | | | | | | | | | | |
| Under 4 million JPY | 168 | 29.7 | 299 | 21.2 | 196 | 24.2 | 226 | 28.3 | 184 | 22.0 | 103.44 |
| 4 to 6 million JPY | 148 | 26.1 | 299 | 21.2 | 193 | 23.8 | 222 | 27.8 | 214 | 25.6 | $p < 0.001$ |
| Over 6 million JPY | 218 | 38.5 | 682 | 48.3 | 291 | 35.9 | 271 | 34.0 | 343 | 41.1 | |
| Unknown | 32 | 5.7 | 132 | 9.3 | 130 | 16.0 | 79 | 9.9 | 94 | 11.3 | |
| Single–person household | | | | | | | | | | | |
| Yes | 131 | 23.2 | 178 | 12.6 | 83 | 10.2 | 111 | 13.9 | 97 | 11.6 | 57.341 |
| No | 434 | 76.8 | 1234 | 87.4 | 727 | 89.8 | 687 | 86.1 | 738 | 88.4 | $p < 0.001$ |
| Under 18 in household | | | | | | | | | | | |
| Yes | 372 | 65.8 | 916 | 64.9 | 550 | 67.9 | 513 | 64.3 | 529 | 63.4 | 4.2798 |
| No | 194 | 34.3 | 496 | 35.1 | 260 | 32.1 | 285 | 35.7 | 306 | 36.6 | $p = 0.370$ |
| Full–time homemaker | | | | | | | | | | | |
| Yes | 57 | 10.1 | 236 | 16.7 | 204 | 25.2 | 192 | 24.1 | 178 | 21.3 | 67.721 |
| No | 509 | 89.9 | 1176 | 83.3 | 606 | 74.8 | 606 | 75.9 | 657 | 78.7 | $p < 0.001$ |
| Education | | | | | | | | | | | |
| Primary and Secondary | 171 | 30.2 | 342 | 24.2 | 263 | 32.5 | 245 | 30.7 | 228 | 27.3 | 85.310 |
| Vocational | 126 | 22.3 | 344 | 24.4 | 275 | 34.0 | 230 | 28.8 | 232 | 27.8 | $p < 0.001$ |
| Undergraduate | 248 | 43.8 | 656 | 46.5 | 250 | 30.9 | 293 | 36.7 | 329 | 39.4 | |
| Postgraduate | 21 | 3.7 | 70 | 5.0 | 22 | 2.7 | 30 | 3.8 | 46 | 5.5 | |

*generous customers*, *attribute–economy balancers*, *price–conscious*, and *conservatives*. Among the five segments, two distinctive comparisons were found regarding the preference toward alternative production systems. One is the comparison between *novelty accepters* and *conservatives*. These two segments differ in the acceptance of alternative production systems, with the former showing the highest acceptance to them, and the latter the lowest. The other is a comparison between three other segments: *generous customers*, *attribute–economy balancers*, and *price–conscious*.

Among these five segments, novelty accepters, comprising about 13% of consumers can be considered to have the highest acceptance toward sustainably grown meats or meat substitutes. This segment had a higher percentage of male (58.8%) where the majority of the respondents were female, the lowest average age, and the highest percentage of single–person households. Although male gender and younger age were characteristics associated with the segment considered price more important over labels on animal-welfare or environment attributes in meat purchase (Koistinen et al., 2013), they were suggested to influence positively to meat substitutes acceptance (Bryant, van Nek, & Rolland, 2020). It should be noted that the relatively small household income relative to disposable income may be a constraint on actual purchasing behavior. Nevertheless, household income does not necessarily reflect the size of household expenditures, and a qualitative study of actual consumption is desirable. On the other hand, *conservatives* showed a lower percentage of respondents in their 20s–30s, a higher percentage of respondents 60 years of age or older, a smaller percentage of single–person households, higher household income, and a higher percentage of respondents who are full–time homemakers. Koistinen also found the characteristics of older age as a characteristic of a segment preferred conventional production methods (Koistinen et al., 2013).

From the perspective of human values, security, benevolence, and universalism are higher and stimulation, achievement, and power are lower than those for *novelty acceptors*. This indicates that *conservatives* segment is stronger in conservation and self–transcendence and weaker in openness to change and self–enhancement in terms of human values, compared with *novelty acceptors*. Conservation and its sub–value, security, are believed to promote the selection of foods that are considered safer. For example, Sonoda et al. found that stronger security values promoted the choice of animal–welfare friendly and eco–friendly labels in an experiment conducted on beef in Japan (Sonoda et al., 2018). Although the present results contradict this, it is possible that the information presented in the experiment was taken differently by two segments. While *conservatives* segment received negative aspect of food safety, for *novelty acceptors* who showed stronger openness to change values than *conservatives*, received positive information contributed to greater acceptance of new products. The fact that self–enhancement, the higher value of achievement and power, is stronger than that for *conservatives* differs from previous report (Vermeir & Verbeke, 2006). Sonoda et al. concluded that this value promotes personal ego and negatively affects altruistic behavior (Sonoda et al., 2018). Given similar reports in a study on organic foods in emerging markets (Mainardes, de Araujo, Lasso, & Andrade, 2017), it is possible that alternative production methods are selected in the choice behavior of inner personal that leads to self–improvement of own welfare or self–satisfaction rather than contribution to the society, and that further investigation is needed.

In terms of scientific literacy, the proportion of *inquisitive* type and *sciencephiles* was similar in both segments, but the proportion of

*life–centered* was lower and the proportion of *low–interest* was higher in *conservatives*. These results suggest that not only knowledge of and interest in science such as food production technologies, but also interest in social issues or the consequences of behavior related to such issues affect respondents' acceptance of alternative production methods. Providing information on effects of meat and meat substitutes consumption on food safety or human health have been identified as an effective consumer communication in the shift to meat alternatives (Bryant et al., 2020; Vinnari & Tapio, 2009).

The adoption of marketing practices such as credence certification setting and labeling based on it from advanced markets such as in Europe (Zwolińska & Żakowska-Biemans, 2021) to enhance consumer communication is a possible implementation in Japanese market. Differences in effective marketing strategy according to consumer characteristics have been reported regarding alternative production methods. For example, for animal–welfare–friendly beef, Massaglia et al. revealed that consumers in the Millennial generation recognized an immediate effect of a classification system of information labels (Massaglia, Merlino, & Borra, 2018). The results of our study suggest that consumer communication that takes into consideration not only sociodemographic heterogeneity, but also human values or scientific literacy would be necessary according to the target consumer segment.

A comparison of the other three segments is appropriate for examining the factors that influence price sensitivity. When looking at human values, *generous customers* were stronger than the other two segments in terms of stimulation and hedonism, which constitute openness to change, and weaker in terms of security and conformity, which constitute conservation. It aligned with the finding from Europe that consumers' self-transcendence and openness to change values had positive relationship between preferences regarding sustainable meat production process (Caracciolo et al., 2016). The results of this study can be interpreted as price sensitivity in terms of how it is balanced with other lifestyle expenditures, and that the purchase of scarce and expensive organic beef in Japan is perceived as a threat when managing household expenditure. This is supported by the sociodemographic: When the three segments are ordered by decreasing price sensitivity, annual household income is shown to be in decreasing order. Apostolidis & McLeay found the segment of consumers who were strongly influenced by the price of meat, and characterized with relatively low income (Apostolidis & McLeay, 2016). This suggests that respondents who make a living from a more limited distribution of disposable income try to protect their livelihoods by being more price–sensitive when choosing organic beef.

A remaining question here is opportunities and barriers regarding the organic beef choice behavior of consumers in these segments. Greater understanding of why and how they are willing to choose and pay premium prices compared with conventional products would contribute to increased attention to such in marketing implementation, support of their value recognition, and promotion of their shift in alternative meat products. Therefore, future qualitative research with these segments is desirable.

## 6. Conclusions, limitations, and future work

This paper aims to examine preferences among Japanese consumers regarding attributes of beef mince and its substitutes using product labeling, to develop consumer segments based on these preferences, and to explore the segment with higher acceptance of replacement of conventional products. This paper also aims to explain intersegment differences from the viewpoints of consumer heterogeneity in human values, scientific literacy, and sociodemographic for a deeper understanding of consumer behavior in each segment. Based on the results of the choice experiment and analysis, five segments were identified and named according to choice behavior. Intersegment differences were found in human values, scientific literacy and sociodemographic. The differences between the accepting and conservative groups regarding alternative production methods are suggested to be openness to change versus conservation and self–transcendence versus self–enhancement in human values. Accepting group had higher proportion of *life–centered* respondents in scientific literacy. Sociodemographic data suggested that the most important factors were gender, age, percentage of single–person households, household income, and percentage of full–time homemakers. Differences in price sensitivity among segments with similar selection behavior based on product attributes may be affected by conservation in human values, and by gender of respondents, percentage of full–time homemakers, and annual household income in demographics. In this case, for alternative production methods, the greater the proportion of male respondents and annual household income, the lower the price sensitivity, and the higher the proportion of full–time homemakers, the higher the price sensitivity. For these segments, communication that balances the transmission of price advantages and the effects of product selection and consumption according to price sensitivity is considered necessary.

As an academic contribution, this report is novel in encouraging consumer demand, an important issue for improving sustainability of protein consumption. In particular, to the best of the authors' knowledge, this report is the first to cover beef and meat substitutes as a report from Japan, where there have been fewer reports than in other markets. We hope that the findings will be useful not only in Japan but also in overseas markets facing similar challenges. In addition, from a marketing perspective, the report presents near–term market prospects or methods of searching for such markets. In particular, we presented specific segments and were able to provide suggestions for formulating specific measures for each segment based on the characteristics of choice behavior, values, and scientific and technological literacy, which we expect to be applied in marketing practice.

This study has some limitations. First, the hypothetical choice experiment that we conducted is not guaranteed to reflect the choice of consumers in real purchasing settings (Hensher, 2010). Second, the information presented to the respondents may have influenced their choice behavior (Risius & Hamm, 2018). The effects of content and media type should be investigated. Third, in addition to the quantitative research in the current study, qualitative research such as interviews with actual consumers is desirable to interpret and bolster the results of this study.

## CRediT authorship contribution statement

**Takuya Washio:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft. **Miki Saijo:** Supervision, Writing – review & editing. **Hiroyuki Ito:** Funding acquisition, Writing – review & editing. **Ken-ichi Takeda:** Funding acquisition, Writing – review & editing. **Takumi Ohashi:** Supervision, Writing – review & editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

The authors do not have permission to share data.

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## Appendix

**Table A1**
Number of segments in latent class analysis.

| Number of segments | Log–Likelihood | AIC | BIC |
|---|---|---|---|
| 2 | −86,590.79 | 173,225.6 | 173,437.1 |
| 3 | −81,523.49 | 163,111.0 | 163,418.6 |
| 4 | −78,428.28 | 156,940.6 | 157,344.3 |
| 5 | −75,887.67 | 151,879.4 | 152,379.2 |
| 6 | −77,386.58 | 154,897.1 | 155,493.2 |

AIC donates the Akaike information criterion.
BIC donates the Bayesian information criterion.

**Table A2**
Results of latent class analysis.

| | | Novelty accepters | | | Generous customers | | | Attribute–economy balancers | | | Price–conscious | | | Conservatives | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $N = 566$, 12.8% | | | $N = 1412$, 31.9% | | | $N = 810$, 18.3% | | | $N = 798$, 18.1% | | | $N = 835$, 18.9% | | |
| Attribute | Level | Coefficient | | Std. Err. | Coefficient | | Std. Err. | Coefficient | | Std. Err. | Coefficient | | Std. Err. | Coefficient | | Std. Err. |
| ASC | | 2.9696 | *** | 0.0436 | | | | | | | | | | | | |
| Production method | Organic | 0.8877 | *** | 0.0723 | 0.0901 | *** | 0.0269 | 0.8069 | *** | 0.1659 | 0.4459 | *** | 0.0749 | −0.2033 | *** | 0.0450 |
| | Animal welfare friendly | 0.8061 | *** | 0.0699 | −0.3722 | *** | 0.0363 | −0.7049 | *** | 0.1271 | 0.0851 | | 0.1061 | −0.8215 | *** | 0.0644 |
| | Plant–based | 0.9225 | *** | 0.0756 | −0.8294 | *** | 0.0652 | −1.7110 | *** | 0.1928 | −0.2614 | * | 0.1253 | −1.6463 | *** | 0.0833 |
| | Cultured | 0.6538 | *** | 0.0663 | −1.8961 | *** | 0.0865 | −2.5107 | *** | 0.0812 | −1.9195 | *** | 0.1426 | −3.1893 | *** | 0.1018 |
| Country of Origin | Australia | 0.4035 | *** | 0.0628 | −0.4058 | *** | 0.0422 | −5.7361 | *** | 0.2857 | −0.1726 | * | 0.0683 | −1.0646 | *** | 0.0727 |
| | United States | 0.0149 | | 0.0444 | −0.5579 | *** | 0.0486 | −5.7637 | *** | 0.2459 | −0.6457 | *** | 0.0870 | −1.1242 | *** | 0.0943 |
| | New Zealand | −1.0179 | *** | 0.0623 | −0.4889 | *** | 0.0319 | −4.0826 | *** | 0.2038 | −0.8338 | *** | 0.0883 | −0.9703 | *** | 0.0572 |
| | Canada | −0.2129 | *** | 0.0478 | −0.4719 | *** | 0.0339 | −3.9949 | *** | 0.1623 | −0.4818 | *** | 0.0808 | −0.8253 | *** | 0.0608 |
| Price | | −0.0035 | *** | 0.0002 | −0.0002 | *** | 0.0001 | −0.0045 | *** | 0.0002 | −0.0102 | *** | 0.0003 | −0.0033 | *** | 0.0002 |

Reference levels are conventional method for production method and Japan for country of origin.
Significance codes: 0 < *** < 0.001 < ** < 0.01 < * < 0.05.

**Table A3**
Results of exploratory factor analysis.

| Items | Factor loadings | | |
|---|---|---|---|
| | Science factor | Social factor | Science appreciating factor |
| I am knowledgeable of science and technology | 0.774 | | |
| I am good at grasping a commonality among things | 0.490 | | 0.342 |
| I wish to know more about science and technology | 0.384 | | 0.361 |
| I am interested in the issue of local society | | 0.826 | |
| I am interested in the issue of welfare. | | 0.673 | |
| I am interested in the issue of culture | | 0.526 | |
| I am interested in the issue of economy | 0.352 | | |
| Scientific findings and technological developments enrich the human society | | | 1.048 |
| I hope scientific thinking prevails more in the society | | | 0.783 |
| I trust scientists and engineers | | | 0.746 |

Answer: 4–point scale measuring (4: agree; 3: slightly agree; 2: slightly disagree; 1: disagree).
Kaiser–Meyer–Olkin measure of Sampling Adequacy: Overall MSA = 0.86.
Bartlett's Test of Sphericity: $ChiSq = 14{,}373.31$, $p = 0.000$.
Extraction method: Maximum likelihood with oblique geomin rotation.
RMSEA = 0.0806.
Chronbach's alpha = 0.87.
Factor loadings |0.3| are not shown.

**Table A4**
Descriptive statistics of scientific literacy scores.

| | | All | | Inquisitive | | Sciencephiles | | Life–centered | | Low–interest | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Mean | Scientific factor | 0.000 | 0.928 | 0.894 | 0.575 | 0.341 | 0.593 | −0.380 | 0.669 | −0.907 | 0.593 |
| | Social factor | 0.000 | 0.939 | 1.013 | 0.546 | −0.144 | 0.454 | −0.132 | 0.826 | −0.876 | 0.613 |
| | Science appreciating factor | 0.000 | 1.006 | 0.678 | 0.641 | 0.758 | 0.573 | −1.041 | 0.889 | −0.344 | 0.507 |
| Population | | 4421 | | 1235 | | 952 | | 1134 | | 1100 | |

All donates the summary of all 4421 samples.
Scores are standardized to a mean of zero.

**Table A5**
Results of k–means clustering.

| | | Inquisitive | Sciencephiles | Life–centered | Low–interest |
|---|---|---|---|---|---|
| Median | Scientific factor | 0.894 | 0.341 | −0.380 | −0.907 |
| | Social factor | 1.013 | −0.144 | −0.132 | −0.876 |
| | Science appreciating factor | 0.678 | 0.758 | −1.041 | −0.344 |
| Population | | 1235 | 952 | 1134 | 1100 |

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