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Research Article

Measuring Consumers' Perceived Bias of the Safety Risk of Domestic Infant Formula with Principal Component Analysis and Multidimensional Model

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There is a large bias between consumers' perception of food safety risks and the actual state of food safety. Accurate measurements of consumers' perceived bias of food safety risk provide a scientific basis for the government to improve food safety risk communication measures. Based on the random sample of 559 consumers obtained by the scenario simulation experiment on domestic infant formula, consumers' perceived bias of the safety risk of domestic infant formula was accurately measured with a principal component analysis and a multidimensional model. The results show that consumers' perceived bias of the safety risk of domestic infant formula includes physical-performance risk, financial-time risk, and psychological risk. The physical-performance risk perception bias is the highest, followed by psychological risk perception bias and financial-time risk perception bias. There are significant differences in the perception bias of the safety risk of domestic infant formula among consumers with different demographic characteristics. The Chinese government could adjust consumers' perceived bias of the food safety risk by establishing a food safety risk communication mechanism, strengthening the popularization of food safety knowledge, and preventing and managing food safety rumors.

1. Introduction

As one of the most important sources of nutrition for nonbreastfed infants, infant formula has become a landmark product regarding food safety issues and a breakthrough for the government to solve these issues due to its special importance [1]. With the Chinese government's introduction of a series of highly stringent policies for governing the infant formula industry, the safety of domestic infant formula, that is, infant formula produced by domestic enterprises or foreign-funded enterprises in China, has been significantly improved, and its safety risks are completely under control [2].

According to the data of the State Administration for Market Regulation of the People's Republic of China, the pass rates of domestic infant formula sampling inspection between 2018 and 2020 were 99.80%, 99.77%, and 99.89%, respectively, and no forbidden additives (e.g., melamine) have been detected for 12 consecutive years [3]. However, due to the lack of confidence in domestic infant formula, consumers tend to overestimate its safety risks and form perception bias [1, 4]. This has resulted in consumer purchase behavior not having recovered yet, as consumers continue to demand imported infant formula, which has weakened the effectiveness of new government policy [5]. According to the statistics of the General Administration of Customs of the People's Republic of China, the import scale of infant formula from 2011 to 2020 increased at an average annual growth rate of 18.06%, from 78,300 tons to 348,600 tons, with an increase of nearly 350% [6]. Currently, the market share of imported infant formula is still higher than that of domestic infant formula.

Previous studies mostly focus on consumers' perception of food safety risks. Accurate measurement of consumers' perception of food safety risks is the basis for these

studies. You and Ju [7] measured Korean consumers' risk perceptions of Chinese processed foods and Japanese seafood imported to South Korea through a psychometric paradigm. Baptista et al. [8] evaluated Brazilian consumers' perception of the risks associated with seafood and revealed a low level of perception of seafood safety risk. Millman et al. [9] assessed British consumers' domestic food risk perceptions through Best-Worst Scaling and analyzed heterogeneity of risk perception between experts and the lay public. Since risk information is a significant determinant of risk perception, some studies have explored the impact of risk information on risk perception. Ha et al. [10] applied Structural Equation Modeling to the survey data from Hanoi, Vietnam, and found that negative information about food safety heightened the risk perceived of common foods and indirectly increased the perception of food safety risk in general. Hilverda et al. [11] conducted an online interaction experiment to examine how social media-mediated interaction with another person impacts Dutch Internet users' risk perception of organic food. Knowledge plays a critical role in risk perception, and some studies have explored the impact of knowledge on risk perception. Miao et al. [12] reported that knowledge would decrease Chinese consumers' risk perception of food additives under the influence of food safety issues' risk perception. Similarly, Jenkins et al. [13] also found that knowledge is crucial in shaping risk perceptions and has implications for risk management. To date, few studies have examined the issue of consumers' perceived bias of food safety risks. Therefore, this paper focuses on domestic infant formula as the research object and aims to accurately measure consumers' perceived bias of the safety risk of domestic infant formula and further compare the differences of consumers' risk perception bias with different demographic characteristics. Finally, recommendations are put forward to adjust consumers' perceived bias of food safety risk. The results provide a theoretical basis and valuable reference to measure consumers' perceived bias of the safety risk of various food products, and the government can improve communication measures of food safety risk based on the measuring results.

2. Theoretical Model

The measurement models for food safety risk perception include a two-factor model and a multidimensional model. Although the two-factor model is easy to use, it has been questioned because the probability and severity of adverse health consequences of food safety risks cannot be accurately determined [14]. The multidimensional model is based on the psychometric paradigm of risk perception theory. This defines risk perception as the sum of different types of losses caused by risks and measures risk perception from different loss dimensions, where results are more scientific, comprehensive, and widely used [15]. Food safety risk perception is usually composed of six dimensions: physical risk, performance risk, financial risk, time risk, social risk, and psychological risk [16, 17]. Therefore, the multidimensional model is constructed to measure consumers' perception of the safety risk of domestic infant formula R_{Subject} (abbreviated as R_S). For clarity of comparison, the real safety risk of domestic infant formula is marked as R_{Object} (abbreviated as R_O).

According to the theory of bounded rationality, consumers are not perfectly rational in reality [18]. Thus, there is a large bias between consumers' perception of food safety risks (R_S) and the actual state of food safety (R_O), that is, risk perception bias. As view of the current safety risk of domestic infant formula is within the complete controlled range, consumers do not overestimate the safety risk when consumers' perception of the safety risk of domestic infant formula is less than or equal to the real safety risk (i.e., $R_S \le R_O$), and there is no risk perception bias. And consumers overestimate the safety risk when $R_S > R_O$; this means there is risk perception bias. Referring to the practices of Qiu et al. [19] and Li and Zhao [20], the difference of R_S and R_O represents consumers' perceived bias of the safety risk of domestic infant formula $R_{\text{Deviation}}$ (abbreviated as R_D,R_D) as expressed by the following formula:

$$R_D = \begin{cases} R_S - R_o & \text{if } R_S > R_o \\ 0 & \text{if } R_S \le R_o \end{cases}. \quad (1)$$

3. Methodology

3.1. Survey Method. Risk assessment techniques cannot measure consumers' risk perception, and the objective results measured by risk assessment techniques cannot be compared with the subjective results of consumers' risk perceptions. Therefore, the situational simulation experiment is adopted to measure consumers' perceived bias indirectly [21, 22]. Compared with a traditional questionnaire, the situational simulation experiment avoids the problem of respondents' memory bias due to the passage of time; thus, the measurement results are more realistic and accurate [23].

However, scenario simulation experiments cannot measure the real safety risk of domestic infant formula. According to the theory of information asymmetry, safety is one of the trust attributes of domestic infant formula, and information asymmetry is the root cause of the risk perception bias [5, 24]. And efficient risk communication aims to improve the supply of risk information and fulfill the need for risk information by individuals [25]. Therefore, we need to make consumers' perception of the safety risk of domestic infant formula in Scenario 2 as close as possible to the real safety risk of domestic infant formula using means of information reinforcement to simulate risk communication [26, 27]. Finally, we need to replace the real safety risk with consumers' perception of the safety risk in Scenario 2.

To avoid the problem of respondents' responses not being completely consistent with real life, respondents must be familiar with the scenario [28]. The scenario set in this paper is the purchase of infant formula, and the specific examples are as follows:

(1) Scenario 1 (measuring consumers' perception of the safety risk of domestic infant formula R_S):

respondents were asked to carefully read a text simulating the purchase of infant formula, which stated, "Suppose you are in the place where you often buy infant formula and need to buy infant formula for your baby. At present, there is a domestic infant formula sold in the place, that is, infant formula produced by domestic enterprises or foreign-funded enterprises in China, which is the infant formula you often purchase or the most common." After reading the text, respondents were asked to answer the questions (Table 1).

(2) Scenario 2 (measuring the real safety risk of domestic infant formula R_O): respondents were asked to carefully read a text with enhanced information, which stated, "According to the data of the State Administration for Market Regulation of the People's Republic of China, the pass rates of domestic infant formula sampling inspection between 2018 and 2020 were 99.50%, 99.80%, and 99.77%, respectively, and no forbidden additives (e.g., melamine) have been detected for 11 consecutive years. In the first half of 2020, the failure rate of domestic infant formula sampling inspection was 0.10%, while the failure rate of the entire food sampling inspection was 2.11%." After reading the text, respondents were asked to answer the questions again (Table 1).

3.2. Questionnaire. The questionnaire consisted of three parts: the first part and the second part were conducted for Scenario 1 and Scenario 2, respectively, and the third part was conducted for the demographic characteristics of consumers, including gender, age, education level, family residence, monthly household income, age of infant, purchasing behavior, and occupation (related to food industry, including food raw material supply, food development, food processing, food marketing, and food safety supervision). The item order was randomized throughout the questionnaire to avoid bias. The questionnaire had an initial part that explained the purpose of the survey and anonymity of the responses.

The 6 items were decided based on mature questionnaires developed by domestic and foreign experts, combined with the characteristics of the safety risk of infant formula. All items were using a 5-point Likert scale ranging from "strongly disagree (1)" to "strongly agree (5)." Specific items are presented in Table 1.

Reliability of the scales was measured using Cronbach's alpha, while validity was measured using Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) test. The values of Cronbach's alpha of scales were 0.719 (Scenario 1) and 0.736 (Scenario 2), respectively, both above 0.700, suggesting adequate reliability of the scale. Bartlett's tests of sphericity were both significant ($p < 0.001$). The values obtained from the KMO test were 0.857 (Scenario 1) and 0.885 (Scenario 2), respectively, both above 0.800, suggesting adequate validity of the scale. These results also suggested that principal component analysis was appropriate for the sample data.

3.3. Sample and Data Collection. Unlike other kinds of food consumption, infant formula consumption has a rigid demand, and there is no significant difference among different regions. Heilongjiang Province is the largest production base of infant formula in China, partnering with domestic and foreign famous brands such as Feihe and Nestle. Therefore, Heilongjiang was selected as the representative province, and six prefecture-level cities (Harbin, Qiqihar, Jixi, Heihe, Hegang, and Qitaihe) were selected by the stratified random sampling method to conduct the survey. The sales locations of infant formula are mainly distributed in urban areas, so shopping malls and supermarkets with relatively dense population in urban areas were selected as the specific investigation location. The main purchasing decision-makers for infant formula in the family were taken as the research object. After unified training and practice tests, the questionnaires were distributed to postgraduates as researchers, to complete the investigation during the school summer holiday in July and August 2020. Simple random sampling was employed to select the respondents, and no more than 10 people were interviewed at the same research site. The interview process was completely voluntary. One hundred questionnaires were distributed in each city, and 600 questionnaires were distributed in total. After eliminating invalid questionnaires with missing data and logical errors, 559 valid questionnaires were obtained, with an effective rate of 93.17%.

In terms of sample distribution, female respondents accounted for more than 70%, which was consistent with the fact that the infant formula market is dominated by female consumers. The respondents aged 25–29 accounted for the largest proportion of nearly 50%; the education level of respondents was mainly undergraduate level, accounting for 47.05%; most of the respondents lived in urban areas, accounting for 71.20% (which is consistent with the fact that urban residents account for more than 60% of the total population in China); the monthly household income of respondents was mainly above 8,000 CNY; the proportion of respondents whose infants were over 6 months old was the largest, accounting for more than 80% (probably because newborns aged 0–6 months were still mainly breastfed, while infants aged over 6 months began to be fed with infant formula); respondents not engaged in food industry accounted for the majority of nearly 90%; more than half of the respondents (52.95%) purchased domestic infant formula, and 47.05% purchased imported infant formula (Table 2).

3.4. Statistical Analysis

3.4.1. Principal Components Analysis. Due to the difference of consumers' perceptions of losses caused by food safety risk, it is necessary to determine the weights of the six dimensions of risk perception in the multidimensional model.

Table 1: Items and references of the questionnaire.

Dimensions	Items	References
Physical risk	I believe domestic infant formula will damage the health and growth of infants	Yang and He [29]
Performance risk	I believe the safety of domestic infant formula does not meet the national standards	Su and Zhang [30]
Financial risk	I believe domestic infant formula will increase medical expenses for infants after they get sick	Danelon and Salay [31]
Time risk	I believe purchasing domestic infant formula would be a waste of my time for repeat purchases	Yeung and Morris [16]
Social risk	I believe my relatives and friends do not approve of my purchase of domestic infant formula	Crespo et al. [32]
Psychological risk	I believe I often worry about the safety of domestic infant formula	Guo et al. [33]

Table 2: Demographics of respondents.

Demographic variables		No. of respondents	% of survey sample
Gender	Female	406	72.63
	Male	153	27.37
Age	20–24	68	12.16
	25–29	257	45.97
	30–34	121	21.65
	35–39	83	14.85
	Above 40	30	5.37
Education level	Primary school or lower	29	5.19
	High school	76	13.60
	College	106	18.96
	Undergraduate	263	47.05
	Graduate	85	15.20
Family residence	Urban	398	71.20
	Rural	161	28.80
Monthly household income	Under ¥4,000	17	3.04
	¥4,001~¥6,000	46	8.23
	¥6,001~¥8,000	60	10.73
	¥8,001~¥10,000	229	40.97
	Above ¥10,000	207	37.03
Age of infant	Pregnant	18	3.22
	0–6 months	70	12.52
	7–12 months	183	32.74
	13–36 months	288	51.52
Occupation related to food industry	Yes	75	13.41
	No	484	86.59
Type of infant formula purchased	Domestic	296	52.95
	Imported	263	47.05

The Principal Components Analysis (PCA) is one of the basic methods of data compression that aims to convert a set of observations of correlated variables into a set of values of linearly uncorrelated variables through mathematical transformation of objective data rather than experts' subjective cognition [34]. After transforming, original variables can be represented by a smaller number of variables while explaining a sufficiently large part of the variability of the original data set [13]. Compared with other weight methods, the PCA not only resolves the information overlap between indicators problems, and the results are objective and reasonable. Therefore, this paper uses principal component analysis to determine the weights of each dimension of consumers' perceptions of safety risk of domestic infant formula.

A set of original indicators $x_1, x_2, \ldots, x_m$ can be organized in a matrix X, and x_{ij} is the generic element that represents the value of variable j on measure i, where $i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, m$. The data matrix X will have dimensions $n \times m$ and can be represented as follows:

$$X = \left(x_{ij}\right)_{n\times m} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix}. \tag{2}$$

In a short form, $X = [x_1, x_2, \ldots, x_m]$.

r_{ij} represents the correlation coefficients of x_{ij} through the formula of the correlation coefficient as follows:

$$\begin{aligned} r_{ij} &= \frac{1}{n-1}\sum_{k=1}^{n}\left(x_{ki}.x_{kj}\right) \\ &= \frac{\sum_{k=1}^{n}\left(x_{ki}-\overline{x_i}\right)\left(x_{kj}-\overline{x_j}\right)}{\sqrt{\sum_{k=1}^{n}\left(x_{ki}-\overline{x_i}\right)^2}\sqrt{\sum_{k=1}^{n}\left(x_{kj}-\overline{x_j}\right)^2}}. \end{aligned} \tag{3}$$

$r_{ij} = r_{ji}$, and $r_{ii} = 1$.

The correlation coefficients matrix R will have dimensions $n \times m$ and can be represented as follows:

$$R = \left(r_{ij}\right)_{n\times m} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{bmatrix}. \quad (4)$$

In a short form, $R = [r_1, r_2, \ldots, r_m]$.

According to the correlation coefficients matrix R, eigenvalues $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_m \geq 0$ and the corresponding eigenvectors $u_1, u_2, \ldots, u_m$ are calculated, and $u_j = (u_{1j}, u_{2j}, \cdots, u_{nj})^T$.

Each principal component F_j is calculated by a linear combination of the original variables x_i.

$$F_j = u_{1j}x_1 + u_{2j}x_2 + \ldots + u_{nj}x_n. \quad (5)$$

The variance w_j of principal component F_j is calculated by the formula

$$w_j = \frac{\lambda_j}{\sum_{k=1}^{m}\lambda_k} \times 100\%, \quad (6)$$

the cumulative variance W_p of principal component $F_1, F_2, \ldots, F_p$ is calculated by the formula

$$W_p = \frac{\sum_{j=1}^{p}\lambda_j}{\sum_{k=1}^{m}\lambda_k} \times 100\%, \quad (7)$$

and the composite score of the principal components is

$$R = \sum_{j=1}^{p}\frac{w_j F_j}{W_p}. \quad (8)$$

The principal component $F_1, F_2, \ldots, F_p$ contains the basic information of the original variables, when W_p is close to 1 (generally greater than 85%).

3.4.2. One-Way ANOVA. One-way ANOVA was adopted to analyze the heterogeneity among consumers' perceived bias of the safety risk of domestic infant formula with different demographic characteristics [35].

Consider an arbitrary sample that consists of k groups of randomly chosen real values. A group $j \in \{1, 2, \ldots, k\}$ contains n_j values $x_{\ell j}$ with $\ell = 1, 2, \ldots, n_j$. Then, $n = n_1 + n_2 + \ldots + n_k$ is the total number of values in the sample.

Standardly, $\overline{x}_j$ and μ_j denote the sample and population means for $j = 1, 2, \ldots, k$.

We tested

$$\begin{aligned} &H_0\colon\ \mu_1 = \mu_2 = \cdots = \mu_k, \\ &H_1\colon \text{not all } \mu_i \text{ are the same, } i = 1, 2, \ldots, k. \end{aligned} \quad (9)$$

The one-way ANOVA test rejects the null hypothesis H_0 with significance α, that is, with confidence $100(1-\alpha)\%$, if and only if

$$F_{\text{stat}} > F_{\text{crit}}(\alpha, k-1, n-k), \quad (10)$$

or equivalently, if the $p-value$ corresponding to F_{stat} is less than α.

Here, $F_{\text{crit}}(\alpha, k-1, n-k)$ is the critical value of the Fisher–Snedecor distribution corresponding to the significance level α, with degrees of freedom of the numerator $df_1 = k-1$ and of the denominator $df_2 = n-k$.

The value F_{stat} is given by the ratio

$$F_{\text{stat}} = \frac{MSA}{MSE}, \quad (11)$$

where

$$\begin{aligned} MSA &= \frac{SSA}{k-1}, \\ SSA &= \sum_{j=1}^{k} n_j\left(\overline{x}_j - \overline{\overline{x}}\right)^2 = \frac{1}{n}\sum_{j=1}^{k}\sum_{i=j+1}^{k} n_j n_i\left(\overline{x}_j - \overline{x}_i\right)^2, \\ \overline{\overline{x}} &= \frac{1}{n}\sum_{j=1}^{k}\sum_{\ell=1}^{k} x_{\ell j} = \frac{1}{n}\sum_{j=1}^{k} n_j\overline{x}_j, \\ MSE &= \frac{SSE}{n-k}, \\ SSE &= \sum_{j=1}^{k}\sum_{i=1}^{n_i}\left(x_{ij} - \overline{x}_j\right)^2. \end{aligned} \quad (12)$$

Thus, ANOVA rejects H_0 if and only if

$$MSE < \left(n(k-1)F_{\text{crit}}(\alpha, k-1, n-k)\right)^{-1} \sum_{j=1}^{k}\sum_{i=j+1}^{k} n_j n_i\left(\overline{x}_j - \overline{x}_i\right)^2. \quad (13)$$

4. Results

4.1. Dimensional Risk Perception. The principal components were extracted according to the criteria of eigenvalues greater than 1 and cumulative variance greater than 85%, and the results of the PCA are shown in Table 3. In both Scenario 1 and Scenario 2, there are three principal components with eigenvalues greater than 1 and cumulative variance of 92.380% and 86.173%, respectively. Consumers' perceptions of safety risk of domestic infant formula can be simplified into three principal components, which contain the basic information.

The three principal components are named uniformly according to the content they described. The point to note here is that the results of Scenario 2 are marked at the upper corner to distinguish the analysis results of Scenario 1 and Scenario 2.

The first principal components F_1 and F_1^* mainly described consumers' perception of physical risk and performance risk of domestic infant formula. The physical risk refers to the loss of domestic infant formula harming the health and growth of the infant, for example, the presence of banned substances in the infant formula causing illness in infants. The performance risk refers to the loss that domestic infant formula cannot meet consumers' expected utility; for example, the infant formula is moldy, which makes it impossible to continue eating. Performance risk is a necessary condition for physical risk; that is, occurrence of physical risk is accompanied by performance risk.

Table 3: Results of Principal Components Analysis.

Dimensions	Scenario 1 (R_S)			Scenario 2 (R_O)		
	Physical-performance risk (F_1)	Financial-time risk (F_2)	Psychological risk (F_3)	Physical-performance risk (F_1^*)	Financial-time risk (F_2^*)	Psychological risk (F_3^*)
Physical risk	0.948	−0.470	−0.306	0.931	−0.349	−0.267
Performance risk	0.925	−0.367	−0.286	0.923	−0.264	−0.234
Financial risk	0.454	0.882	0.340	0.436	0.823	0.321
Time risk	0.465	0.729	−0.311	0.457	0.867	−0.309
Social risk	0.266	0.231	−0.254	0.103	0.133	−0.209
Psychological risk	0.317	0.349	0.950	0.249	0.297	0.941
Eigenvalue	2.348	1.840	1.355	2.190	1.726	1.254
Variance (%)	39.132	30.669	22.579	36.504	28.774	20.895
Cumulative (%)	39.132	69.801	92.380	36.504	65.278	86.173

Therefore, the first principal components F_1 and F_1^* are named physical-performance risk.

The second principal components F_2 and F_2^* mainly described consumers' perception of financial risk and time risk of domestic infant formula. The financial risk refers to the loss of consumers' property caused by domestic infant formula; for example, consumers need to repurchase due to the purchase of expired formula. The time risk refers to the loss of consumers' time caused by domestic infant formula, for example, consumers wasting personal time to exchange or refund with the seller. Both finances and time are opportunity costs, and the safety problems of domestic infant formula generally cause additional time investment and financial expenditure for consumers. Therefore, the second principal components F_2 and F_2^* are named financial-time risk.

The third principal components F_3 and F_3^* mainly described consumers' perception of psychological risk of domestic infant formula. Psychological risk refers to consumers' self-emotional harm caused by the purchase decision error, for example, the negative emotions of remorse, anxiety, or fear. The loading matrix coefficient of social risk was relatively low and failed to form a principal component, indicating that social risk was not the main source of consumers' perceptions of safety risk of domestic infant formula. Therefore, the third principal components F_3 and F_3^* are named psychological risk.

The variance of physical-performance risk was greater than that of financial-time risk and psychological risk, indicating that physical-performance risk was the primary resource of consumers' perceptions of safety risk of domestic infant formula (Table 3).

In summary, the multidimensional model to measure consumers' perception of the safety risk of domestic infant formula R_S is

$$\begin{cases} R_S = 0.42360F_1 + 0.33199F_2 + 0.24441F_3, \\ F_1 = 0.948Ph + 0.925Pe + 0.454Fi + 0.465Ti + 0.266So + 0.317Ps, \\ F_2 = -0.470Ph - 0.367Pe + 0.882Fi + 0.729Ti + 0.231So + 0.349Ps, \\ F_3 = -0.306Ph - 0.286Pe + 0.340Fi - 0.311Ti - 0.254So + 0.950Ps. \end{cases} \tag{14}$$

The multidimensional model to measure consumers' perception of the safety risk R_O, which replaces the real safety risk, is

$$\begin{cases} R_O = 0.42361F_1^* + 0.33391F_2^* + 0.24248F_3^*, \\ F_1^* = 0.931Ph^* + 0.923Pe^* + 0.436Fi^* + 0.457Ti^* + 0.103So^* + 0.249Ps^*, \\ F_2^* = -0.349Ph^* - 0.264Pe^* + 0.823Fi^* + 0.867Ti^* + 0.133So^* + 0.297Ps^*, \\ F_3^* = -0.267Ph^* - 0.234Pe^* + 0.321Fi^* - 0.309Ti^* - 0.209So^* + 0.941Ps^*, \end{cases} \tag{15}$$

where Ph and Ph^* are abbreviations for physical risk, Pe and Pe^* are abbreviations for performance risk, Fi and Fi^* are abbreviations for financial risk, Ti and Ti^* are abbreviations for time risk, So and So^* are abbreviations for social risk, and Ps and Ps^* are abbreviations for psychological risk.

4.2. Risk Perception Bias. In general, consumers overestimate the safety risk of domestic infant formula, forming risk perception bias (Table 4). Therefore, consumers' perceived bias of food safety risk is mainly pessimistic bias, meaning that consumers tend to believe that food safety risk is extremely likely to happen to them [36]. When consumers consider a major threat to their interests, especially under the influence of multiple factors such as politics, media, and culture, they develop negative emotions such as anxiety, fear, and anger, making it impossible for them to perceive food safety risks rationally [37]. According to prospect theory, consumers are generally "loss averse" and "obsessed with small-probability events" when they are making decisions with bounded rationality and are quick to overestimate the probability and the severity of food safety risk, resulting in risk perception bias [38].

Specifically, as shown in Table 4, physical-performance risk perception bias is the highest (1.687), psychological risk perception bias is the second highest (1.372), and financial-time risk perception bias is the lowest (0.173). On the one hand, in pursuit of exposure, the media (the primary source of food safety information) tends to report negative food safety information, which puts emphasis on the uncertainty and harmfulness of food safety risk [39]. These reports consisted largely of the performance problem of food and physical harm caused by food safety risks [40]. Coupled with the preference for negative food safety information of consumers who are risk-averse, consumers generally overestimate the food safety risk [41]. On the other hand, only consumers who have personally experienced food safety problems will clearly perceive the financial loss and time loss, while most consumers have not experienced food safety problems. Therefore, the perception bias of physical-performance risk and psychological risk is relatively high, and the perception bias of financial-time risk is relatively low.

4.3. Heterogeneity among Different Demographic Characteristics. Risk perception is a mental activity process for consumers. Because of the differences in the mental activity process among consumers with varying demographic characteristics, their risk perception bias is also different [42]. In order to understand the heterogeneity of risk perception bias of domestic infant formula among consumers with different demographic characteristics, one-way ANOVA tests were conducted by selecting gender, age, education level, family residence, monthly household income, age of the infant, purchasing behavior, and occupation.

As shown in Table 5, there were significant differences in the risk perception bias of domestic infant formula among consumers with different education levels ($F = 5.632$, $p = 0.000$), monthly household incomes ($F = 5.362$, $p = 0.000$), purchasing behavior ($F = 5.996$, $p = 0.000$), and occupation ($F = 8.271$, $p = 0.000$).

The risk perception bias decreases as the education level increases (Figure 1). The main reason for this is that consumers with higher education levels have stronger food safety information-seeking abilities and wider access to information and tend to perceive risk more rationally and objectively.

The risk perception bias decreases with higher monthly household income (Figure 2). Generally, higher-income consumers are better able to avoid food safety risk. When purchasing food with a safety risk, they can take more measures to avoid them, such as purchasing alternatives at a higher price and therefore lower risk. In fact, according to the survey results, the higher-income sample usually chose to purchase certified organic infant formula at a higher price and better quality.

The risk perception bias of consumers who purchased domestic infant formula is significantly lower than that of consumers who purchased imported infant formula (Figure 3). Generally, there is an interrelationship between risk perception and purchasing behavior. On the one hand, according to prospect theory, consumers tend to be risk-averse and purchase alternatives to avoid food safety risk. On the other hand, according to decision-making theory, consumers' risk perception would be influenced by the evaluation results of purchasing behavior. Therefore, consumers who purchase domestic infant formula have a relatively low-risk perception which will further promote consumers to purchase domestic infant formula.

The risk perception bias of consumers engaged in food industry is significantly lower than that of consumers not engaged in food industry (Figure 4). Because consumers engaged in food industry usually have knowledge of food safety risks, they can perceive food safety risk more scientifically and professionally.

As shown in Table 5, the differences in risk perception bias of domestic infant formula among consumers of different genders, ages, family residence, and ages of infants were not significant.

Females are the main consumer group in the infant formula market. As mothers of infants, they are more concerned about and more sensitive to the health of infants. Although the risk perception bias of female consumers was higher than that of male consumers, the difference is not statistically significant ($F = 2.253$, $p > 0.100$). This may be because the decision to purchase infant formula is made jointly by parents.

Compared with younger consumers, older consumers are more concerned about food safety and the health of their families. However, the difference of consumers' risk perception bias with different age is not statistically significant ($F = 1.149$, $p > 0.100$). This may be because respondents aged 20–29 accounted for more than 50% of the sample.

Since the specific investigation locations of the survey are mainly in urban areas, respondents living in rural areas have typically worked in urban areas for a long time. There is no statistically significant difference in risk perception bias between urban respondents and rural respondents ($F = 1.872$, $p > 0.100$).

With the growth of infants, consumers knowledge about infant formula probably increases with the purchasing amount increase. However, as a staged consumer product, infant formula does not have a long and continuous consumption cycle. The effects of the accumulation of

Table 4: Results of consumers' risk perception bias measurement.

Dimensions	Scenario 1 (R_S)	Scenario 2 (R_O)	Risk perception bias (R_D)
Physical-performance risk	6.778	5.091	1.687
Financial-time risk	3.741	3.568	0.173
Psychological risk	5.388	4.016	1.372
Safety risk	5.430	4.322	1.108

Table 5: Results of one-way ANOVA.

Demographic characteristics	F – value	p – value	Significance
Gender	2.253	0.106	Not significant
Age	1.149	0.333	Not significant
Education level	5.632***	0.000	Significant
Family residence	1.872	0.155	Not significant
Monthly household income	5.362***	0.000	Significant
Age of infant	1.151	0.332	Not significant
Purchasing behavior	5.996***	0.000	Significant
Occupation	8.271***	0.000	Significant

Note: ***indicates significance at levels of 1%.

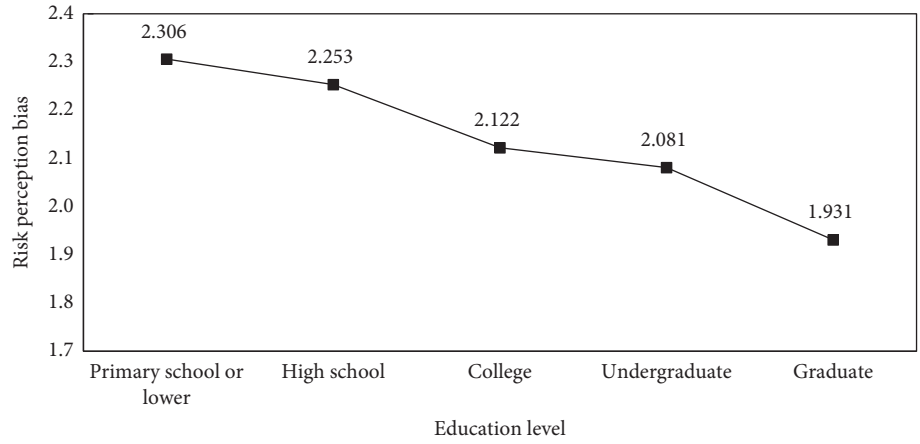

Figure 1: Consumers' risk perception bias with different education levels.

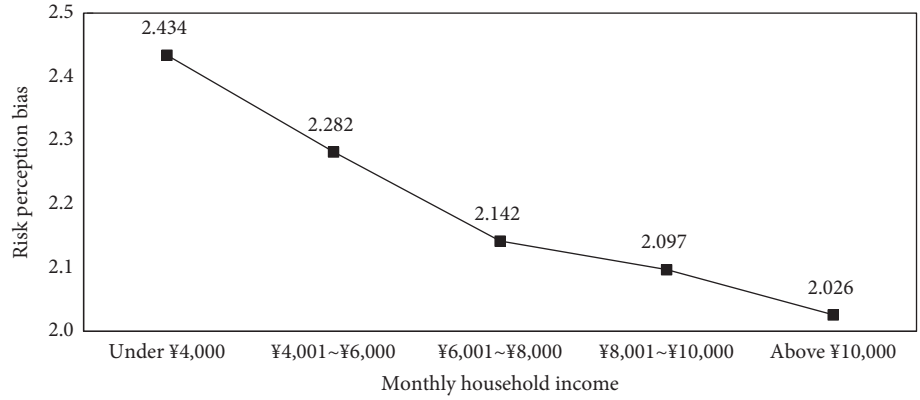

Figure 2: Consumers' risk perception bias with different monthly household incomes.

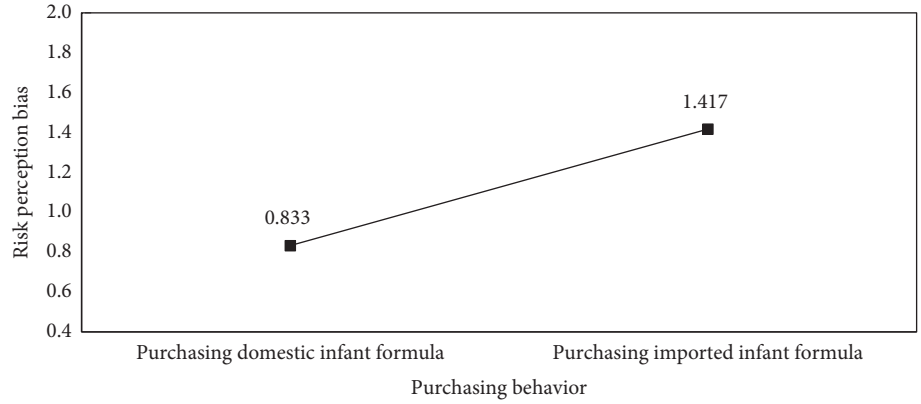

Figure 3: Consumers' risk perception bias with different purchasing behaviors.

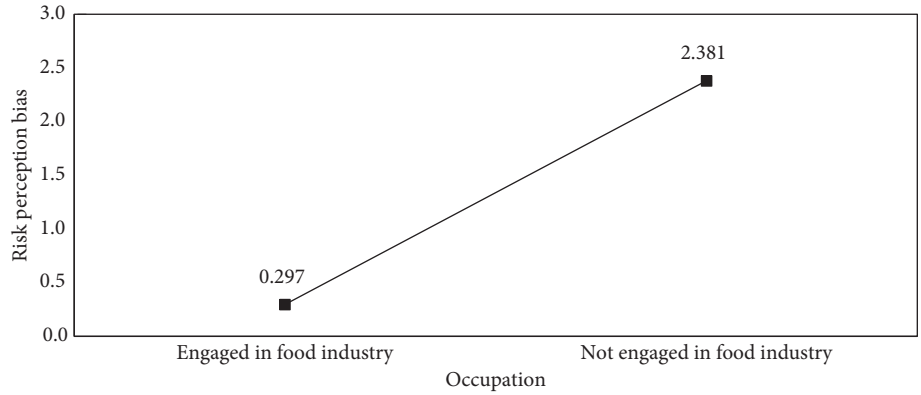

Figure 4: Consumers' risk perception bias with different occupation.

knowledge on consumers' risk perception bias are insignificant. Therefore, the age of the infant has minimal effect on risk perception bias, and there is no statistically significant difference in risk perception bias among consumers with different infant ages ($F = 1.151$, $p > 0.100$).

5. Conclusions and Recommendations

The negative impact of consumers' food safety risk perception on the food industry is much greater than the food safety risk itself. Understanding consumers' risk perception bias is important for improving the food safety governance system. Based on the random sample of 559 consumers obtained by the scenario simulation experiment, this paper accurately measured consumers' perceived bias of the safety risk of domestic infant formula with principal component analysis and multidimensional model and further analyzed the heterogeneity among different demographic characteristics. The results show the following: First, food safety risk communication measures can effectively adjust consumer risk perceived bias. Second, consumers' perceived bias of the safety risk of domestic infant formula is mainly composed of physical-performance risk, financial-time risk, and psychological risk. Third, the physical-performance risk perception bias was the highest, followed by the psychological risk perception bias and lastly the financial-time risk perception bias. Forth, there are significant differences in the perception bias of the safety risk of domestic infant formula among consumers with different education levels, monthly household incomes, purchasing behavior, and occupation. The perception bias of the safety risk of domestic infant formula is relatively lower among consumers with higher education, with higher monthly household incomes, who purchased domestic infant formula, and who engaged in food industry.

This paper used the example of domestic infant formula, a special food related to the well-being of hundreds of millions of families and the future of the nation, to measure consumers' risk perception bias. It is currently very common for consumers to overestimate food safety risks. Information asymmetry is the root reason for risk perception bias, and strengthening food safety risk communication is an important way to regulate consumers' food safety risk perception bias. Therefore, the government should improve food safety risk communication measures as one of the key tasks of food safety. Specific recommendations are as follows.

First, establish a food safety risk communication mechanism. ① Establish a food safety risk communication platform between enterprises, suppliers, associations, media, and consumers to solve the problem of information asymmetry. ② Disclose food safety information to the

public regularly through the platform and entrust experts and researchers to interpret the information. ③ Encourage food production enterprises to respond directly to consumers through the platform to avoid consumer confusion and misunderstanding.

Second, strengthen the popularization of food safety knowledge. ① Organize regular food safety science and education activities and encourage the participation of multiple bodies, including research institutes, universities and colleges, associations, and enterprises through multiple channels, for example, schools, media, and communities. ② Arrange professional salespersons to explain the food safety situation and answer questions to consumers. ③ Focus on the primary audience of food safety knowledge popularization, including groups not engaged in food industry, groups with lower education levels, and groups with lower monthly household incomes.

Third, prevent and manage food safety rumors. ① Establish an intelligent platform for capturing, identifying, analyzing, and disposing of rumors. ② Refute and delete information that has been confirmed as rumors in time. ③ Crack down on rumors, fraud, and false propaganda resolutely in accordance with the law to prevent rumors from interfering with consumers' rational cognition.

The survey data of this study were obtained from Heilongjiang Province, so the conclusions and recommendations must be understood in the context of certain limitations. With the rising market share of domestic infant formula, consumers' risk perception bias may be reduced through consumers' own positive postpurchase evaluation and positive reputation of other consumers. In the future, we can consider expanding survey scope and using panel data to further analyze the heterogeneity and dynamics of consumers' perceived bias of the safety risk of domestic infant formula and its influencing factors.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding this work.

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