Objective risk and subjective risk: The role of information in food supply chains

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Abstract

Food-borne infections cause a considerable amount of illnesses, heavily affecting healthcare systems. Given the spread of food-borne infections, assessing food risks is a relevant issue for the food industry and policymakers. Following a systematic and meta-analytical approach, we evaluate how different sources and types of risks (i.e. objective and subjective) are valued by consumers, in order to emphasise to what extent information on food risks may be efficiently transferred to consumers. The results show that information on food safety, conveyed through labels, exerts a positive influence on the premium prices for food safety. Consumers would be willing to pay a price premium up to 168.7% for food products that are treated against a specific food-borne risk factor, certified to be safe, tested or even inspected by public or third parties. However, we also find that labels are inefficient instruments of information on food safety, particularly when products are likely to be affected by hazardous and risky events and consumers correctly perceive risks. The results suggest that consumers exposed to relevant risk information about food safety tend to increase their risk perception and to decrease their premium prices for information on food safety. Including labels on food safety may fill the information gap and thus lower the mismatch between (objective) scientific-based risks and (subjective) perceived risks.

Keywords: Ambiguity; Consumer; Food safety; Information; Label; Risk.

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1. Introduction

Food-borne infections are a major cause of illness and death worldwide (Ifft et al., 2012; De Groote et al., 2016), as stated by the World Health Organisation (WHO) in its Global Strategy for Food Safety[1]. In developing countries food-borne infections lead to the death of many children (Kosek et al., 2003), and affect children's growth and their cognitive development (Black et al., 1984; Guerrant et al., 1999). Also, in developed countries a considerable amount of illnesses is caused by food-borne infections, thus heavily affecting healthcare systems (Britwum and Yiannaka, 2019).

Animal-based foods are widespread all over the world and often considered the key cause of the increase in food-borne infections. We provide some emblematic examples. Eggs are used as an ingredient in a wide range of foods, but the complexity of such foods associated with the large number of ingredients, make it difficult to ascribe the resultant diseases to a particular ingredient (Hessel et al., 2019). However, about 70% of complex foods associated with illness are egg-based or include eggs as an ingredient (Addak et al., 2005). The complex foods which contain eggs are considered a major source of infection for food related diseases. Addak et al. (2005) find that eating shellfish (a luxury food with relatively low consumption levels) is associated with a very high disease risk. Although the number of cases attributed to shellfish are in the same ranges or levels as beef or eggs, the level of risk is much higher (Gillespie et al., 2001). Pre-harvesting contamination of oysters with norovirus has a major impact on generating cases of disease (Addak et al., 2005). Red meat (e.g. beef, lamb, pork) contributes heavily to deaths, despite lower levels of risk (e.g. Rodrigues et al., 2001; Neimann et al., 2003). However high risks, in terms of severity of illness, are also associated with eating chicken (Torija et al., 2003) which has a lower disease risk ratio than shellfish or turkey, but a higher hospitalisation risk ratio. A further issue for animal-based food is

[1] The Strategy consists of seven approaches developed to reduce the health and social burden of food-borne disease: (i) strengthening surveillance systems of food-borne diseases; (ii) improving risk assessments; (iii) developing methods for assessing the safety of the products of new technologies; (iv) enhancing the scientific and public health role of WHO in Codex; (v) enhancing risk communication and advocacy; (vi) improving international and national cooperation; (vii) strengthening capacity building in developing countries. The goal of reducing the health and social burden of food-borne disease will be achieved through three principal lines of action: (1) advocating and supporting the development of risk-based, sustainable, integrated food safety systems; (2) devising science-based measures along the entire food production chain that will prevent exposure to unacceptable levels of microbiological agents and chemicals in food; (3) assessing and managing food-borne risks and communicating information, in cooperation with other sectors and partners (World Health Organisation, 2002).

the possibility of developing antimicrobial resistance. Fighting against antimicrobial resistance is a priority for many countries (O'Brien, 2014). In 2011 the European Commission launched a 5-year Action Plan against the rising threats from antimicrobial resistance, with a set of rigorous measures to fight against the use of antimicrobials, particularly in the dairy sector.

Assessing food risks is a relevant issue for the food industry and for policymakers (Ververis et al., 2020). The risks in the food sector are several, of various nature and, potentially, responsible for direct and indirect costs. Direct costs are mainly due to the adoption of *ad hoc* protocols and standards, aimed at limiting contamination and propagation of pathogens (e.g. product recalls, Britwum and Yiannaka, 2019; disposal of food and feed, De Groote et al., 2016). Indirect costs are associated with the potential reduction of sales, due to food scares, or sales restrictions imposed by penalties (e.g. reduced consumption of certain categories or brands until the situation returns normal, Grunert, 2005). While the scientific progresses contribute to the limitation of direct costs, understanding the perception of risks is a more demanding challenge, particularly because of the number of factors involved in consumer choices. The numerosity and complexity of food risks make it challenging consumers' choices, and the design of policy interventions and marketing campaigns.

Apart from the main drivers of consumers behaviour (e.g. price, income, tastes), an important role is played by the individual attitudes (e.g. neophobia, neophilie) (Grunert, 2005). For new products, the attitudes toward potential risks associated with consumption (i.e. risk aversion) is also important. The decisions under uncertainty are taken after having considered several factors (e.g. risk attitude and risk perceptions) and having processed the information provided to consumers (Cao et al., 2015). In this framework, departures from rationality and non-coherent choices with respect to risky decisions may help explaining consumers' choices. An example of low-rational (or non-rational) attitude is the attitude towards ambiguity. The ambiguity aversion, that is the aversion of economic agents (i.e. consumers) when facing risky situations in which the probabilities associated with risks are unclear, affects consumers behaviour (see Ellsberg, 1961). The attitude toward ambiguity is due to incomplete information, and to differences in capability of processing information (Fox and Tversky, 1995), in the channels through which information are conveyed and in the cognitive process guiding consumers in processing information.

The current literature has not yet deepened on some of these issues. A recent systematic review by Frewer et al. (2016) emphasises how food risk communication interventions influence risk attitudes and behaviours. The authors show that research interest has been relatively recent and conclude on three relevant themes for developing best practices in risk communication: the characteristics of the target population; the information contents; the features of the information sources. The study also concludes that the literature falls short in quantifying the gap between objective risks and subjective risks and how the communication may reduce the mismatch.

We use a systematic and meta-analytical approach to evaluate how different sources and types of risks (i.e. objective and subjective) are valued by consumers and conclude on how the information on food risks may be efficiently transferred to consumers to reduce the gap between objective and subjective risks.

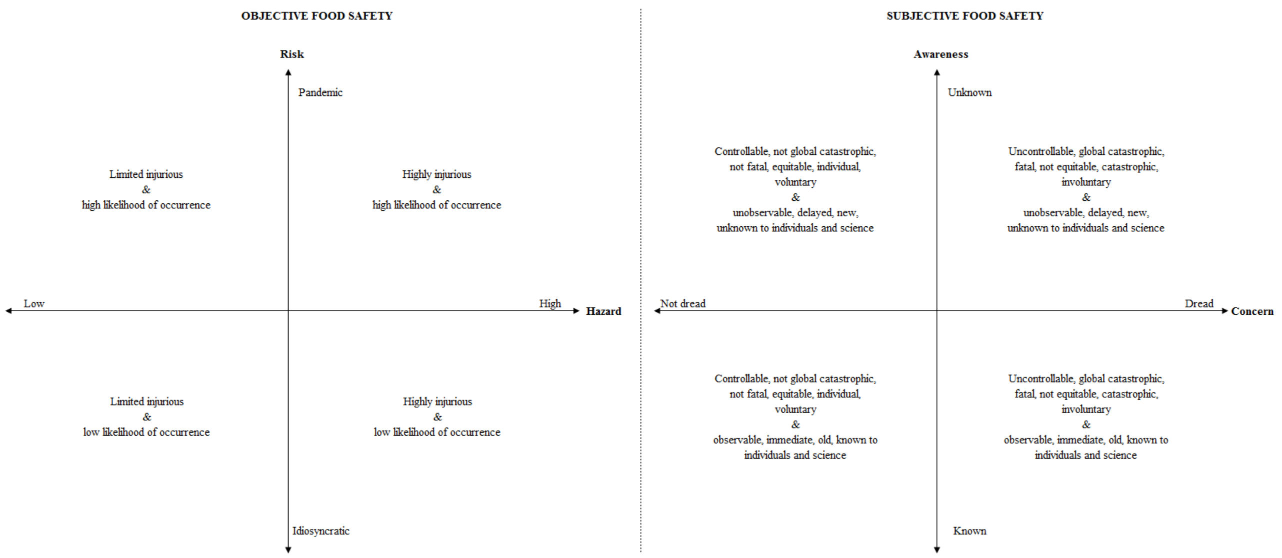
The remainder of the article is organised as follows. The next section details the conceptual framework implemented to classify objective and subjective food-borne risk factors: the objective food safety is declined in terms of hazard and risk; the subjective food safety depends on (perceived) consumers' concerns and awareness. Section 3 describes the protocol adopted to review of literature on consumers' evaluation of information on food safety, and to examine the effects of information and types of risks, using an index of the willingness to pay for food safety. The results, presented in section 4, are organised in three subsections: first, we classify food-borne risk factors and show the divergences between (scientific) objective and (perceived) subjective food safety; second, we describe how the index of willingness to pay varies depending on the types of information and risks; third, we deepen on cases in which the objective and the subjective risks match. The last section concludes with implications for the food industry and for policymakers.

2. Conceptual framework

The definition of food safety covers nutritional quality of food, wide-ranging concerns related to novel food (e.g. unfamiliar properties of genetically modified food), microbiological and chemical safety (Ritson and Mai, 1998). *Stricto sensu*, food safety may be defined as *"the inverse of food risk – the probability of not suffering some hazard from consuming the food in question"* (Henson and Traill, 1993, p. 153).

According to Grunert (2005), food safety may be objective or subjective. Objective food safety is a concept based on the assessment of the risk of consuming a certain food by scientists and food experts. Subjective food safety is a concept linked to the consumers' perception of the risks associated with the consumption of unsafe food. The level of objective and subjective food risks may diverge: the former is due to (objective) scientific evidence of food safety; the latter depends on individuals' (subjective) perceptions of risks and safety.

Figure 1. Dimensions of objective and subjective food safety.



Notes: elaboration on Slovic (1987) and Henson and Traill (1993).

From the perspective of objective food safety, the potential adverse impact of consuming unsafe food has two components: hazard and risk (figure 1). Hazard refers to the severity of the adverse impact; risk refers to the likelihood of occurrence of the hazard[2] (Henson and Traill, 1993). A particular food-borne risk factor may have a very low hazard (i.e. limited effects) but a high risk due to a high likelihood of occurrence (e.g. salmonella outbreak). Vice-versa, a food-borne risk factor may be highly injurious, thus highly hazardous, but it may have a low risk due to a low likelihood of occurrence (e.g. botulism).

In terms of subjective food safety, risk perception has been widely since the pioneering work by Fischhoff et al. (1978) and Slovic (1987). Frewer et al. (2005) observe that self-imposed risk tends to be more acceptable than technology-based risk (i.e. voluntariness). Risk perception tends to be characterised by an optimistic bias which is the believe that the likelihood of being hit by a risk factor is lower than the likelihood of the average individual being hit by the same risk factor (Grunert, 2005). Several studies also demonstrate the relevance of the dimensions of dread and knowledge or familiarity in risk perception of certain categories such as new technologies or novel foods (e.g. Scholderer and Frewer, 2003; Frewer et al., 2003, 2004). Our conceptual framework assumes that the individuals may have aversion to some food-borne risk factor and be indifferent to others, depending on their judgments about risks and hazards of potential impact of consuming unsafe food[3]. However, these reactions (aversion *versus* indifference) may differ from the opinions of experts (objective food safety). According to Slovic (1987), the individuals' judgments are related to awareness and concerns about potential impacts associated with the consumption of

[2] According to the risk management guidelines defined in ISO 31000:2018, risk is the effect of uncertainty on objectives and is usually expressed in terms of risk sources (i.e. element which alone or in combination has the potential to give rise to risk), potential events (i.e. occurrence or change of a particular set of circumstances), their consequences (i.e. outcome of an event affecting objectives) and their likelihood (i.e. chance of something happening). In our study we consider a specific risk source (i.e. food) and potential event (i.e. food-borne risk outbreak) and define its consequences as limited or high injurious (i.e. low or high hazard) and its likelihood of occurrence as low (i.e. idiosyncratic risk) or high (i.e. pandemic risk).

[3] Variability in risk perceptions may depend on social, cultural, and institutional factors, as well as on intra-individual differences determined by past experiences (Barnett and Breakwell, 2001). The experience acquired in past hazardous activities is likely to reduce the imperfect knowledge of decision-makers (Santeramo, 2019). However, the relationship between risks and past experiences depends on whether the hazardous activity is voluntary or involuntary. Voluntary risks are perceived to be an individual choice, whereas involuntary risks are perceived as unfamiliar, uncontrollable and involuntary (Twigger-Ross and Breakwell, 1999).

unsafe food (figure 1). As for the awareness, the individuals may perceive a food-borne risk factor as known (i.e. observable, old, immediate in its manifestation of effects, and known to those exposed to its effects and to science) or unknown (i.e. unobservable, new, delayed in its manifestation of effects, and unknown to those exposed to its effects and to science). In terms of concerns, a food-borne risk factor may be perceived as not dreadful (i.e. characterised by controllability, not catastrophic potential, not fatal consequences, equitable distribution of risks and benefits, voluntary) or dreadful (i.e. characterised by lack of control, catastrophic potential, fatal consequences, inequitable distribution of risks and benefits, involuntary).

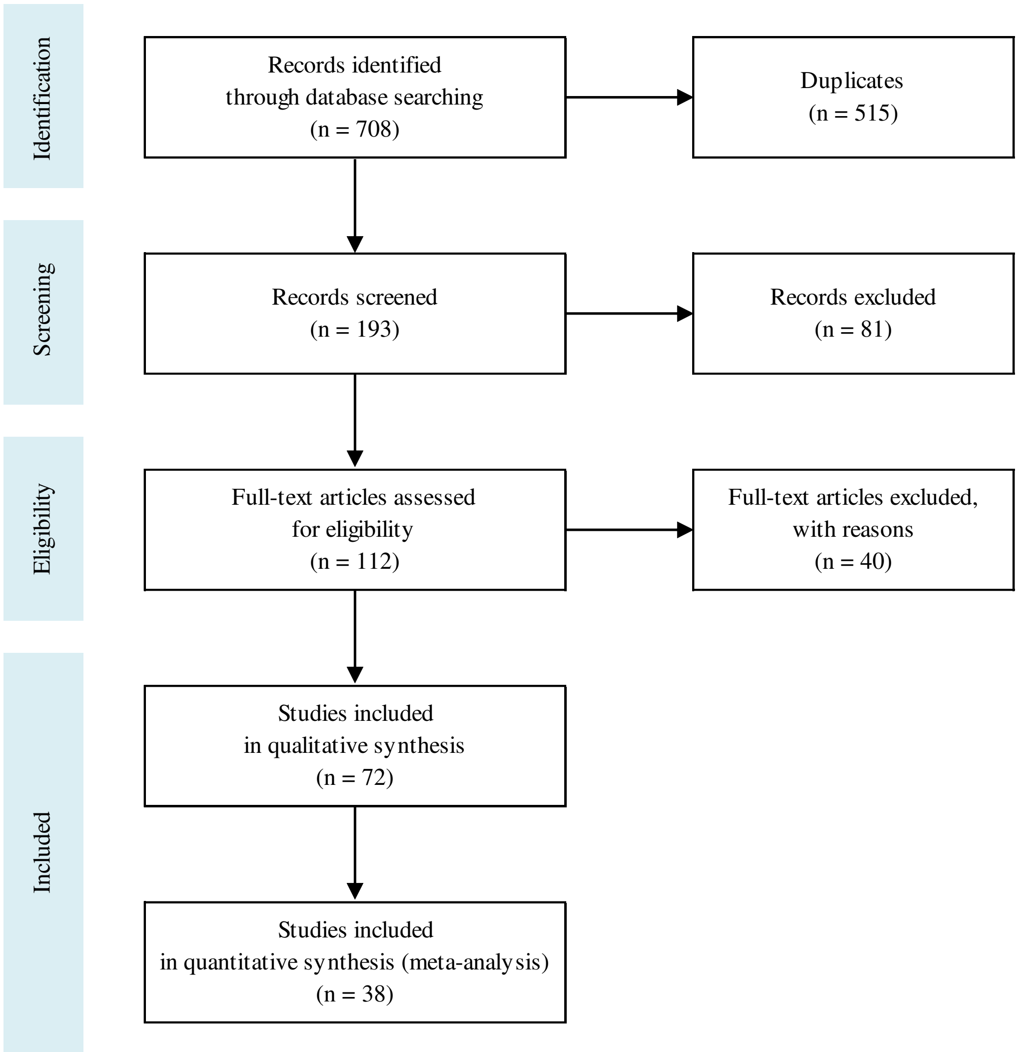
3. Methodological approach

3.1. Search strategy and inclusion/exclusion criteria

We systematically reviewed the literature on consumers' evaluations of information on food safety, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol (Moher et al., 2009; Shamseer et al., 2015). The systematic review, conducted in June 2019, includes articles published in Scopus. We limited the search to the subject area "Economics, Econometrics and Finance" to select only articles published in top field journals.

We run 6 separate searches to identify a set of articles (708) which contains all possible combinations of keywords in their title, abstract or keywords. We used the following string: ["willingness to pay"] AND ["food safety"] AND ["behaviour" OR "choice" OR "consumer"] AND ["claim" OR "label"]. After removing duplicates, the articles (193) were screened based on the information contained in their title, abstract, and full text: a set of 112 articles were assessed for eligibility, 72 articles were included in the qualitative synthesis, and 38 of them were included in the quantitative analysis (figure 2, table 1).

Figure 2. Process of articles' selection.



Source: elaboration on PRISMA flow diagram.

[Table 1]

In order to be included in the sample, the articles had to meet two general criteria: (i) the provision of consumers' attitudes and responses to information in a food safety context; (ii) the detection of information on consumers' intention to buy or pay for information on food safety. The first criterion allowed us to select articles on consumers' perspective. The second criterion limited the results to the articles containing valuations of information on food safety (as a function of the reported parameter). The articles that did not meet the inclusion criteria were excluded from the sample. Finally, we did not consider conference proceedings, but only peer-reviewed articles published in English, so to make our analysis widely and easily replicable (Dias and Mendes, 2018).

3.2. Data extraction

From the set of 38 articles included in the quantitative synthesis, we collected the following data: (i) general information on the article, (ii) information on methodological and structural issues, and (iii) specific information related to food safety. In particular, we retrieved the list of authors, the year of publication, the journal in which the article is published, the subject area to which the journal belongs, other than the subject area “Economics, Econometrics and Finance”, the rank of the journal provided by the Scimago Journal & Country Rank (SJR) at the date of publication as refereed to the subject area “Economics, Econometrics and Finance” the number of citations for each article, collected in July 12, 2019, and the title, scope, and main findings.

As for information related to methodological and structural issues, we reported the experimental designs used to conduct the research (e.g. choice experiment, field experiment, experimental auction), the empirical models used to analyses survey data (e.g. random parameter logit model, multinomial logit model, probit model, mixed logit model), the sample size, the country analysed in the article, and the specific product under investigation in the article and related product category (e.g. meat, fish, dairy, fruit and vegetables).

As for the specific information related to food safety, we extracted the food-borne risk factors under investigation in the article (e.g. Bovine spongiform encephalopathy –BSE– crisis, new technologies, mycotoxin contamination, dioxin contamination), the estimated coefficients and related standard errors (or t-statistics) for label and/or claim related to food safety, a detailed description of label and/or claim related to food safety (e.g. fed with direct-fed microbials, vaccinated against Escherichia coli, recombinant Bovine somatotropin –rBST– free, BSE tested), the estimated coefficients and related standard errors (or t-statistics) for price, the currency, quantity, and reference price[4] available in the market for the product under investigation, the reported willingness

[4] Following Lusk et al. (2005), we used the average value of the price treatments as reference price in articles where a reference price is not given.

to pay (WTP) for label and/or claim related to food safety, if available, and the formula used to compute WTP, if available.

Due to multiple estimates per article, we collected 403 observations. For each observation of the same article, we took note of substantial differences, such as the label and/or claim to which the estimated parameter refers to, the specification of the empirical model (e.g. basic, additional control factors), the sample size and its characteristics (e.g. whole sample or a specific segment). The information on standard errors (or t-statistics) allowed us to select only relevant data: after removing not statistically significant observations, the final sample consists of 257 observations[5].

Following the conceptual framework described in section 2 (figure 1), we classified each food-borne risk factor under investigation in terms of dimensions of objective and subjective food safety. We adopted the classification used in Henson and Traill (1993) and distinguished between hazards and risks associated with a food-borne risk factor. According to the severity of adverse consequences, a categorical variable classifies food-borne risk factors in low hazard (category equal to -1), baseline hazard (category equal to 0), high hazard (category equal to 1). Depending on the likelihood of occurrence, a categorical variable equals -1 for idiosyncratic risk, 0 for the baseline risk, 1 for pandemic risk. We replicated the taxonomy of Slovic (1987) to describe the food-borne risk factors analysed in our sample of articles according to individuals' perception in terms of awareness and concern. We used a categorical variable to classify a food-borne risk factor in known (category equal to -1), baseline awareness (category equal to 0), unknown (category equal to 1). Another categorical variable equals -1 for food-borne risk factors perceived as not dreadful, 0 for the baseline concern, 1 for food-borne risk factors perceived as dreadful. The categorical variables for dimensions of objective and subjective food safety are synthesised in table 2.

[Table 2]

We also generalised information retrieved from the detailed description of label and/or claim related to food safety so to have 5 types of label on food safety. A dummy variable identified observations

[5] The initial sample consisted of 40 articles and 280 observations. We removed two articles (Ifft et al., 2012 and Savchenko et al., 2018) since they contain not statistically significant observations for our variable of interest.

referred to “free” label (e.g. hormone-free, antibiotic-free, rBST free, GMO-free). Another dummy equals 1 if the estimated parameter for information on food safety indicates that a product is treated against food-borne risk factors (e.g. fed with direct-fed microbials, vaccinated against Escherichia coli, BSE tested), and 0 otherwise. Further dummies include labels to indicate if a product is safe (e.g. enhanced food safety) or traced (e.g. DNA traced). Lastly, a dummy variable equals 1 if the estimated parameter for information on food safety is related to inspections (e.g. inspected by FDA, inspected by USDA, inspected by private third parties).

Several computational techniques are used to derive WTP. For instance, while most articles (e.g. Loureiro and Umberger, 2007; Grebitus et al., 2013; Lewis et al., 2017) adopt the traditional ratio between the parameter estimated for food safety and the negative of the estimated parameter for price, some articles (e.g. Tonsor, 2011; Wolf et al., 2011) multiply this ratio by 2, due to the use of effect coded variables for information on food safety. In other cases, formulas reported for WTP are not replicable. In order to avoid the loss of information on WTP (in case of WTP not reported) and due to the adoption of different methods to derive WTP, we built an *ad hoc* normalised index of WTP, based on the information on food safety.

3.3. Deriving an index of WTP for information on food safety

The articles in the sample are choice experiments[6] simulating real-world decisions, developed under the random utility theory (McFadden, 1974) and Lancaster’s theory (1966) to determine the utility the *n*-th individual obtains choosing the *j*-th alternative. According to Lancaster’s theory (1966), the utility is derived from the characteristics (attributes) of the products: the individuals perceive differentiated products as a set of different attributes, independently evaluated at the time of decision according to individual preferences. The utility function is as follows:

$$U_{nj} = V_{nj} + \varepsilon_{nj}; \quad \text{with} \quad V_{nj} = \boldsymbol{\beta}'\boldsymbol{x}_{nj} \tag{1}$$

[6] Observations based on other experimental designs (e.g. field experiment, experimental auction) were lost during the process of selecting statistically significant parameters.

where the utility of individual n from the alternative j (U_{nj}) is a function of a deterministic component (V_{nj}) and a stochastic component (ε_{nj}), unknown and treated as random. V_{nj} is linear and separable in observable attributes of the alternatives ($\boldsymbol{x}_{nj}$), and $\boldsymbol{\beta'}$ is a vector of random parameters representing individual preferences. The estimates of random parameters, $\boldsymbol{\beta'}$, are interpreted in relative terms as they represent changes in utility with respect to the omitted alternative.

Individuals maximise their utility according to their budget constraints (Lancaster, 1966). If the utility is additively separable, individuals have to solve a set of maximisation problems for each product attribute. Given the stochastic nature of the utility function, the maximisation problem is solved probabilistically:

$$\begin{aligned} P_{ni} \quad &= Pr\big(U_{ni} > U_{nj}\big);\ \forall j \neq i, \forall J \\ &= Pr\big(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}\big);\ \forall j \neq i\ \forall J \\ &= Pr\big(\varepsilon_{nj} - \varepsilon_{ni} < V_{nj} - V_{ni}\big);\ \forall j \neq i\ \forall J \end{aligned} \tag{2}$$

According to the equation (2), the probability of choosing alternative i (P_{ni}) equals the probability that the associated utility (U_{ni}) will provide the highest utility for the n-th individual among a set of J alternatives.

Based on this framework, from each article of the sample, we collected parameters representing the individual preferences for food safety (β_k) and for price (β_p) attributes of the product. We derived an index of WTP for information on food safety using the following formula:

$$Index_{WTP} = {\left(-\frac{\beta_k}{\beta_p}\right)}\Big/{P_{ref}} \tag{3}$$

The WTP is computed as ratio between the estimated parameter for food safety and the negative of the parameter estimated for price ($-\beta_k/\beta_p$): each ratio is the price change associated with food safety attribute in a given product. We normalise the derived WTP using a reference price for the product (P_{ref}): this normalisation clear differences in terms of timing, units of measure (e.g. kilograms, pounds) and currencies. The normalising procedure of WTP is a well-adopted technique in meta-analyses involving evaluation of labelled attributes (e.g. Lusk et al., 2005; Deselnicup et al., 2013).

The index computed in equation (3) is a percent variation in WTP and represents the premium price for the information on food safety. A detailed analysis of premium prices for information on food safety, reported in table 3 shows that, on average, consumers are willing to pay about 40-50% more for having more information on food safety. However, cross-country variability exists, as shown by the heterogeneous premium prices across currencies. The observations for Vietnam Dong (VND) are related to the study by Thai et al. (2017) who investigated consumers' preferences and WTP for different attributes of Vietnamese Good Agricultural Practices (VietGAP) vegetables. The deviation found for VND is abnormally low and distant from the sample average: thus, we opt for the elimination of these observation from the sample to avoid biased results. The final sample consists of 251 valid observations.

[Table 3]

Besides the case of VND, Euro (EUR) and Japanese Yen (JPY) tend to be the most (+111.76%) and the least (+25.64%) sensitive currencies, respectively. We also observe a great variability across product categories: dairy products are more sensitive in countries using British pound (GBP, +116.52%) or Chinese Yuan (CNY, +101.32%) than countries using US Dollar (USD, +16.72%); in contrast, the premium price for meat-based products is the highest in countries using USD (+57.49%) and the lowest in countries using GBP (+19.12%); the European countries are more sensitive to fish products (+315.56%).

3.4. Quantitative analysis of meta-data

We followed a meta-analytical approach to investigated how premium prices for information on food safety (i.e. $\text{Index}_{\text{WTP}}$) is affected by label information regarding food safety, as well as by the objective and subjective dimensions of food safety. We run a least square regression of the following empirical model:

$$Index_{WTP} = \lambda + \mathbf{K}\rho + \mathbf{X}\varphi + \mathbf{Z}\omega + \nu \quad (4)$$

where $Index_{WTP}$ is a 251×1 vector of observations on the dependent variable (i.e. index of WTP); λ is a 251×1 vector of constant terms; **K** is a 251×4 matrix of variables including label information on food safety, ρ is the corresponding 4×1 vector of regression coefficients; **X** is a 251×m matrix of interaction terms between label information on food safety and dimensions of objective and subjective food safety, φ is the corresponding m×1 vector of regression coefficients; **Z** is a 251×12 matrix of control factors related to the publication process, ω is the corresponding 12×1 vector of regression coefficients; ν is a 251×1 vector of error terms assumed to be independently and identically distributed.

The matrix **K** includes dummy variables for label information on the level of food safety (i.e. treated, safe, inspected, traced). In our sample, the observations associated to products treated against food-borne risk factors (e.g. fed with direct-fed microbials, vaccinated against Escherichia coli, BSE tested) are 11.2%. The labels indicating that a product is generally safe (e.g. enhanced food safety) or traced (e.g. DNA traced) account for 17.1% and 30.7% of cases. Lastly, 20.3% of observations include label information on food safety related to institutional inspections (e.g. inspected by FDA, inspected by USDA, inspected by private third parties) (table 4). The remaining observations refer to "free" label (e.g. hormone-free, antibiotic-free, rBST free, GMO-free): this variable serves as baseline[7].

To capture the role of information on different types of food-borne risk factors, the matrix **X** includes, alternatively, different interaction terms between information on food safety and dimensions of objective and subjective food safety. First, we create interactions between different labels and food-borne risk factors characterised by high hazard or pandemic risk (objective dimensions of food safety), and unknown or perceived as dreadful by consumers (subjective dimensions of food safety). The label 'treated' is associated with food-borne risk factors hazardous (2.4%), risky (2.4%) and unknown (11.2%); the label 'safe' is associated with food-borne risk

[7] The choice of this variable as baseline is motivated by the higher correlation of such a variable with dummies for other labels (i.e. treated, safe, inspected, traced).

factors risky (3.6%) and unknown (3.6%); the label ‘inspected’ is associated with food-borne risk factors hazardous (1.2%), risky (1.2%), unknown (8.0%) and dreadful (7.2%); the label ‘traced’ is associated with food-borne risk factors unknown (14.7%) and dreadful (6.4%) (table A.1). Second, we control for the extreme dimensions of food safety. We observe a match between labels with food-borne risk factors characterised by high hazard and pandemic risk for ‘treated’ (2.4%) and ‘inspected’ (1.2%), and with food-borne risk factors unknown and dreadful for ‘inspected’ (6.8%) and ‘traced’ (2.8%); in contrast, the match with food-borne risk factors characterised by low hazard and idiosyncratic risk occurs for ‘treated’ (2.4%) and ‘inspected’ (1.2%), whereas food-borne risk factors known and not dreadful are associated with the labels ‘inspected’ (6.8%) and ‘traced’ (2.8%) (table A.1). Lastly, we control for the effects of labels when objective and subjective food safety are the same, that is when hazardous or risky food-borne factors are unknown for consumers or perceived as dreadful. The unknown food-borne risk factors characterised by high hazard or pandemic risk are associated with the labels ‘treated’ (2.4%) and ‘inspected’ (1.2%); in 3.6% of cases the label ‘safe’ is associated with unknown and pandemic risk (table A.1).

As in Santeramo and Lamonaca (2019), the matrix of control factors, **Z**, includes information on the prestige and subject area of the journal in which each article is published. Dummies control for articles published in journals in 25th (Q1), 50th (Q2) and 75th (Q3) percentiles, according to the rank provided by Scimago Journal & Country Rank (SJR) at the date of publication. Note that the sample does not include studies published in journals ranked as Q4, while observations represent 28%, 55%, 15% in Q1, Q2, and Q3 journals, respectively: the remaining 2% of observations belong to an article published in a journal not ranked in SJR (Owusu-Sekyere et al., 2018) and serves as a baseline. Recall that we selected articles published in journals belonging to the subject area Economics, Econometrics and Finance, another dummy indicates if the journal in the sample belongs to the subject area Agricultural and Biological Sciences: this occurs in 73% of cases and allows us to account for the multidisciplinary character of the issue. **Z** includes control variables for the presence of influential authors. We have dummies which indicate scholars who authored at least three articles in the sample: they are C. Grebitus (co-author of 3 articles), M. Chen (co-author of 3 articles), W. Hu (co-author of 6 articles), N.J. Olynk Widmar (co-author of 4 articles), D.L. Ortega (co-author of 3 articles), H. Wang (co-author of 5 articles), L. Wu (co-author of 5 articles), D. Zhu (co-author of 3 articles).

The model in equation (4) is estimated through least squares in different specifications. First, we estimate the effects of information on food safety and test the robustness of the model controlling for different combinations of control factors. Once the role of label information in affecting premium prices for food safety has been identified, we assessed to what extent the effect of label information on food safety vary depending on dimensions of objective and subjective food safety. In particular, we disentangled the net effect of label information on food safety associated with food-borne risk factors characterised by high hazard or pandemic risk (objective dimensions of food safety), and unknown or perceived as dreadful (subjective dimensions of food safety). We then quantified the effects of label information on food safety associated with food-borne risk factors objectively least (i.e. low hazard and idiosyncratic risk) and most (i.e. high hazard and pandemic risk) dangerous, and subjectively most hazardous and risky (i.e. unknown and dreadful)[8]. Lastly, we controlled for the effects of label information on food safety when the subjective perception of consumers equals the objective risk and hazard associated with a food-borne risk factor[9].

[8] We do not estimate the counterpart for least hazardous and risky (i.e. known and not dreadful), from a subjective perspective, due to the lack of data related to food-born risk factors known and perceived as not dreadful (see table A.1).

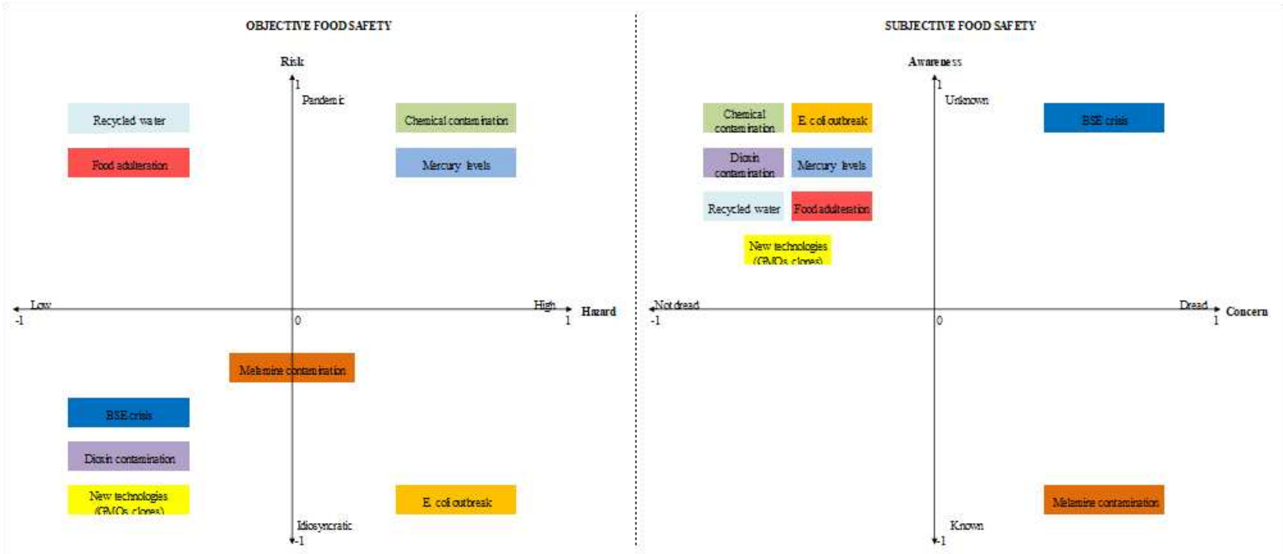
[9] We do not estimate the counterpart for food-born risk factors characterised by high hazard or pandemic risk and perceived as dreadful by consumers, due to the lack of evidence in our sample (see table A.1).

4. Results and discussion

4.1. Classification of food-borne risk factors

Following the conceptual framework described in section 2, we classified each food-borne risk factor, analysed in the sample of articles[10], in terms of objective and subjective dimensions of food safety (figure 3).

Figure 3. Classification of food-borne factors according to dimensions of objective and subjective food safety.



Notes: BSE crisis, Dioxin contamination, E. coli outbreak, Food adulteration, Mercury levels, New technologies (GMOs, clones) are food-borne factors generally related to seafood and meat-based products whose perception is affected by the specific origin of food products (i.e. local versus imported production).

From an objective perspective, most articles analyse food-borne risk factors characterised by low (48.2%) or baseline (45.8%) hazard, and idiosyncratic (46.6%) or baseline (41.8%) risk (table 4). Some examples of food-borne risk factors whose effects are both generally limited (i.e. low hazard) and less likely to occur (i.e. idiosyncratic risk) are BSE crisis (e.g. Peterson and Burbidge, 2012; Lim and Hu, 2016; Lewis et al., 2017), dioxin contamination of animal feed (e.g. Wägeli et al.,

[10] The classification of food-borne risk factors, reported in figure 3, has been validated by a panel of experts (both biologists and food scientists).

2016), new technologies and genetically modified food (e.g. Brooks and Lusk, 2012; Grebitus et al., 2013; Kemper et al., 2018). They are rather frequent in our sample, representing 42.6% of the cases. Food-borne risk factors that are highly hazardous and risky, such as chemical contamination (e.g. Glenk et al., 2012) or mercury levels (e.g. Fonner and Sylvia, 2015), occur in 6.0% of the cases only (figure 3, table 4).

As for the subjective dimensions of food safety, most of food-borne risk factors are perceived as not dreadful (39.8%) or characterised by baseline concern (41.8%), while they are unknown for consumers in 54.2% of the cases (table 6). Only BSE crisis (e.g. Peterson and Burbidge, 2012; Lim and Hu, 2016; Lewis et al., 2017) are unknown for consumers and perceived as dreadful (14.4%), whereas several food-borne risk factors are perceived as not dreadful although unknown (39.8%), examples are chemical contamination (e.g. Glenk et al., 2012), food contamination and adulteration (e.g. Ortega et al., 2014), mercury levels (e.g. Fonner and Sylvia, 2015), Escherichia coli outbreak (e.g. Britwum and Yiannaka, 2019) (figure 3, table 4).

[Table 4]

As evident from figure 3, there is frequently a discrepancy between objective and subjective food safety: remarkable examples are the so-called food scares, such as BSE crisis or dioxin contamination, and certain production technologies, such as food irradiation, genetically modified food, cloning technologies. We find that the perception of food-borne factors generally related to seafood and meat-based products (e.g. BSE crisis, dioxin contamination, e. coli outbreak, food adulteration, mercury levels, new technologies) tends to be affected by the specific origin of food products (i.e. local *versus* imported production). As suggested in Ortega et al. (2014), given the increased attention to food safety scandals at the international level, consumers tend to have a higher valuation for domestic rather than for imported products. While this is an opportunity for domestic producers to dominate the national market, net-importer countries may benefit from more stringent inspection systems to ensure that imported products comply with proper safety requirements. The origin of food products is directly related to concerns about food safety. In fact, consumers tend to use information on origin of food as a food safety cue (Santeramo and Lamonaca, 2020a, b). For instance, Umberger et al. (2003) conclude on the preference of US consumers for domestic beef due to food safety concerns about imported beef; similarly, Lewis et al. (2017) found that the British and the German consumers are willing to pay a premium for domestic beef as compared to imported beef and the premium price increases as the importance consumers attach to food safety increases. Consumers' preferences are likely to be influenced by cultural identities which are determinant in orienting consumers in their evaluation of food risk (Kemper et al., 2018). In cases in which major food scares are perceived, the perception of risks tends to drive food choices and lead individuals to avoid certain categories or brands until the situation returns normal; in the case of new technologies, which use is perceived as unsafe, the individuals tend to develop negative attitudes towards their use (Grunert, 2005). Although new technologies are introduced to provide advantages to consumers, they are applied in different country-specific regulatory frameworks that tend to drive the overall perception of consumers (Grebitus et al., 2018; Santeramo et al., 2018).

The wide divergence between subjective perceptions and objective evidence of the risk of a hazard occurring is a well-known characteristic of consumers' attitudes to risk in food consumption. While scientists are more concerned about microbiology contamination, the consumers tend to overestimate the probability of rare events and underestimate moderate to high probabilities (Cao et al., 2015). Besides the objectivity of a food-borne risk factor, an optimistic bias occurs in risk perception: individuals frequently believe that they are less likely to be exposed to a risk than other individuals, an example is the perception of personal food safety hazards, such as food poisoning contracted at home or inappropriate dietary choices (Grunert, 2005; Cao et al., 2015).

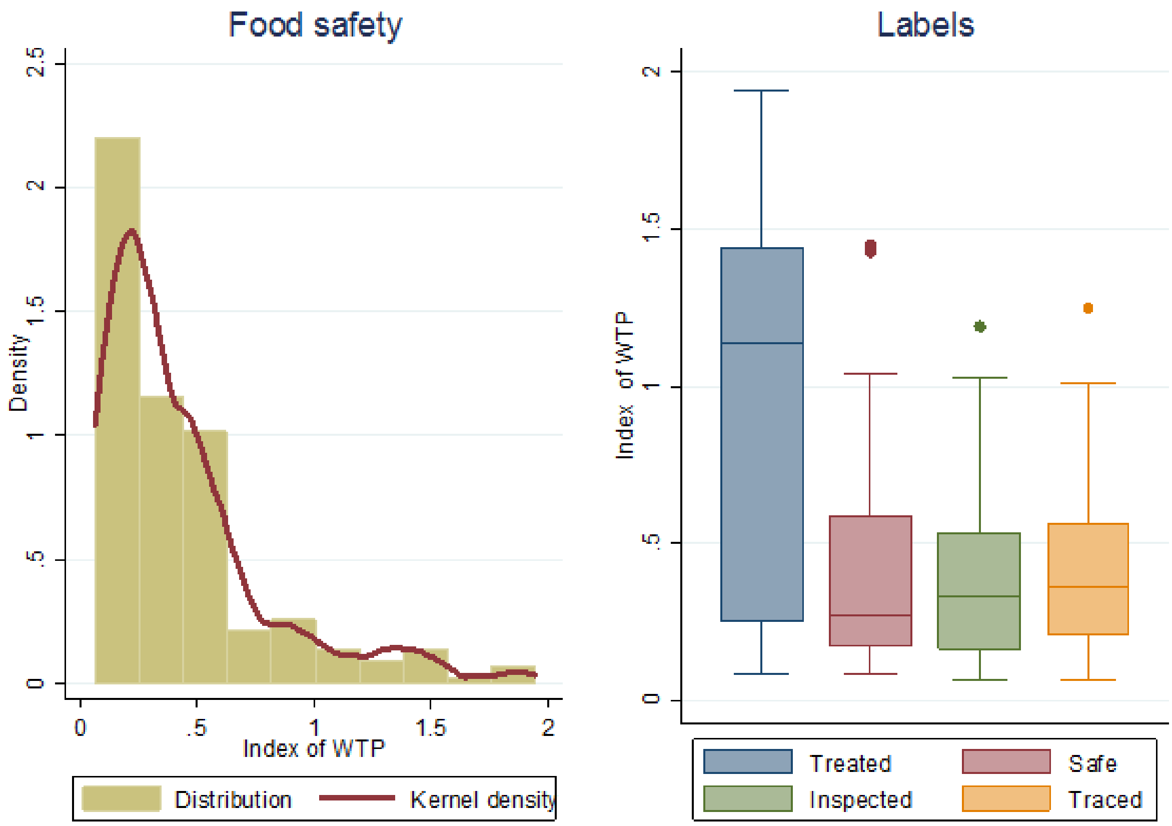
In our sample, objective equals subjective food safety only in a few cases. For instance, this is true for Escherichia coli outbreak (e.g. Britwum and Yiannaka, 2019), chemical contamination (e.g. Glenk et al., 2012), mercury levels (e.g. Fonner and Sylvia, 2015), food contamination and adulteration (e.g. Ortega et al., 2014), recycled water (Savchenko et al., 2018), unknown for consumers, but also characterised by high hazard (6% of cases) or pandemic risk (11.6% of cases) (figure 3).

4.2. Analysis of index of WTP for information on food safety

The empirical distribution of the index of WTP for information on food safety in our sample is shown in figure 4. Excluding the outliers, the index ranges between 0 and 2, it is positive skewed (skewness equal to 4.94) and it is distributed with mean 0.59 and standard deviation 0.91, with a median value equal to 0.33.

The premium prices for information on food safety conveyed through labels ‘safe’, ‘inspected’ and ‘traced’ tend to be lower and less dispersed than the premium price for a label including information about whether a certain product is treated against a specific food-borne risk factor (e.g. vaccinated against Escherichia coli, BSE tested): on average, consumers are willing to pay 42.0%, 39.3% and 42.2% more for products carrying the labels ‘safe’, ‘inspected’ and ‘traced’, respectively, but the premium price is 90.4% greater for the label ‘tested’. The large variability of the index for the label ‘tested’ (0.649) is plausibly due to the fact that, in general, the impact of information about an issue with potential negative effects (e.g. BSE crisis) is larger than that with positive effects (e.g. enhanced safety, traceability) (Cao et al., 2015).

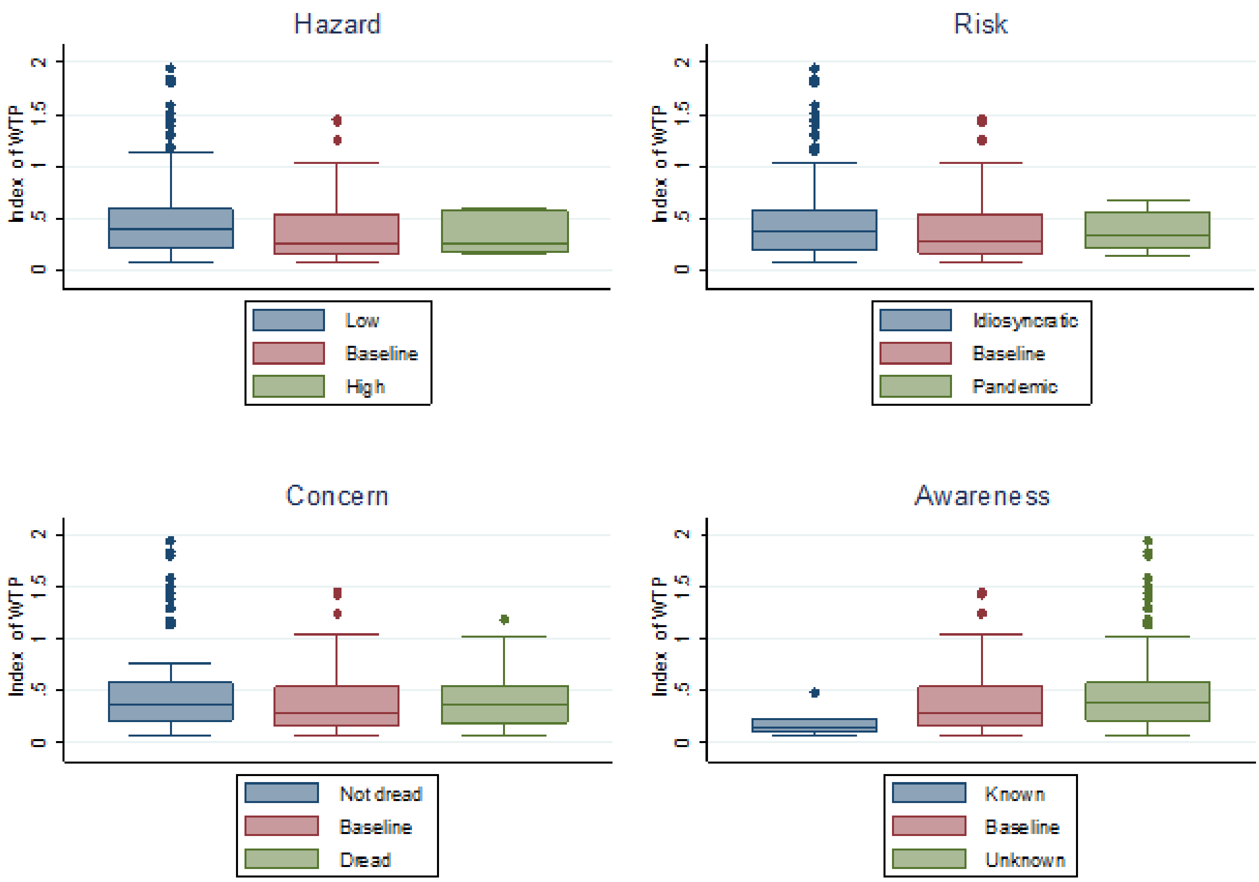
Figure 4. Distribution of index of willingness-to-pay (WTP) for information on food safety.



Notes: Kernel density is built on values of index of WTP within 5th and 95th percentiles.

The figure 5 shows the empirical distribution of the index of WTP for information on food safety in terms of dimensions of food safety. Considering objective dimensions of food safety, the higher the hazard or the risk, the lower the dispersion of the index. On average, the premium price is 31.3% greater for products potentially subject to high hazard and 37.5% higher for products vulnerable to pandemic risks. As for perceived food safety, the index of WTP is almost equally distributed across different levels of concern, with an average premium price of 49.9% for not dreadful risks and 42.1% for dreadful risks. Differently, the premium price for information on food safety increases as the awareness of consumers decreases. On average, consumers are willing to pay 19.7% more to be informed on known risks, but 48.7% more, for information on unknown food-borne risk factors. Our results suggest that the consumers tend to give more importance to unknown (e.g. BSE crisis) rather than to known (e.g. melamine contamination) food-born risk factors. For instance, they would pay a premium price higher for BSE-tested beef (+48.7%) as compared to powder milk traced to avoid melamine contamination (+19.7%). Differences in WTP for unknown and known food-borne factors may be related to the immediacy of health consequences. The longer the time lapse between consumption and symptoms due to food-borne factors, the higher the willingness to pay to avoid long-term concerns (Lagervist et al., 2013). As observed in Cao et al. (2015), consumers systematically overestimate events with relatively low risk, such as technological-related food contamination (i.e. unknown food-borne risk factors), but underestimate factors that may represent a threat to human health, such as Escherichia coli outbreak or chemical contamination (i.e. highly hazardous, but perceived as not dreadful).

Figure 5. Distribution of index of willingness-to-pay (WTP) for objective and subjective dimensions of food safety.



Notes: Distributions consider values of index of WTP within 5th and 95th percentiles.

In the few cases in which the discrepancy between objective and subjective food safety is null, consumers are willing to pay 23.0% and 41.5% more for products potentially exposed to unknown events respectively characterised by high hazard and pandemic risk.

4.3. Meta-regression results

The results reported in table 5 show how the WTP is affected by labels providing information on food safety. The information on food safety, conveyed through labels ‘treated’, ‘safe’ and ‘inspected’, and the premium price for food safety are positively correlated with premium price. The results are consistent with previous studies which found substantial WTP estimates for products with different food safety labels (e.g. Wongprawmas and Canavari, 2017). The results are robust to different combinations of control factors. Coefficients estimated for labels capture most variability in the WTP index. A few exceptions are the negative and significant coefficients estimated for the dummies Olynk Widmar N.J. and Agricultural and Biological Sciences: note that the former, significant at the 5% level in the specification (3), loses significance in favour of the latter in the specification (4).

Focusing on the results reported in column (4), we observe that a label containing information that a certain product is treated against a specific food-borne risk factor increases by 71.4% the premium price for that product. A study that examines WTP for two food safety enhancing technologies that would offer protection against major food-borne pathogens (Britwum and Yiannaka, 2019) found that consumers are willing to pay to be protected against harmful pathogens, and place a premium on ground beef treated against Escherichia coli bacteria.

Our results also show that consumers are willing to pay 53.6% more for a product carrying a label certifying its safety. As shown in previous studies (e.g. Wolf et al., 2011; Carlucci et al., 2017), consumers are generally willing to pay substantial premiums for products with assured food safety enhancement.

In addition, if the food safety of a product is inspected by public or private third parties, the premium price for the inspected product is 43.7% greater. This evidence echoes findings from previous studies highlighting that consumers are concerned about BSE and are willing to pay extra for certainty BSE-tested beef over the standard government surveillance and protocols (e.g. Lim et al., 2013; Lim and Hu, 2016).

Our results suggest that consumers would be willing to pay a price premium of up to 168.7% for food products that are treated against a specific food-borne risk factor, certified to be safe, tested or inspected by public or third parties.

[Table 5]

Once the effects of information on food safety is identified, we assess to what extent these effects vary if associated with food-borne risk factors characterised by high hazard or pandemic risk (objective dimensions of food safety), and unknown or perceived as dreadful (subjective dimensions of food safety).

[Table 6]

The main results are confirmed: information on food safety conveyed through labels and premium prices for food safety are positively correlated (see table 5). We observe a few exceptions in specifications that controls for subjective dimensions of food safety. In particular, the coefficient estimated for label 'safe' loses statistical significance in the specification that controls for unknown food-borne risk factors. As for the coefficients estimated for labels 'inspected' and 'traced', the former loses statistical significance in the specification that controls for food-borne risk factors perceived as dreadful; the latter gains statistical significance in the specification that controls for unknown food-borne risks. The instability of the estimated coefficients is plausibly dependent on the subjective perception of food safety. As also demonstrated in Yin et al. (2019), consumers with different levels of food safety risk perceptions have drastically different WTP for diverse labels. In fact, from a subjective perspective, labels are inefficient vehicles of information on food safety, when products are likely to be affected by food-borne risk factor unknown or perceived as dreadful.

If a product is potentially exposed to an unknown food-borne risk factor, the premium price for that product, carrying the label 'traced', decreases by 112.2% and the net effect of information is negative (-51.6%). Besides this exception, the index of WTP does not vary across dimensions of subjective food safety. With uncertainty, consumers tend to interpret information according to their needs, thus inadequately selecting signals (Verbeke 2005).

Considering food-borne risk factors objectively hazardous and risky, premium prices for labels 'treated' and 'inspected' tend to be reduced. The estimated coefficients are significantly negative. In particular, the premium price for a label containing information that a certain product is treated against a food-borne risk factor is reduced by 113.3% if the severity of consequences is high and even more, by 143.5%, if the risk is pandemic. Similarly, premium prices for products inspected by public or private third parties are 123.7% and 157.9% lower if associated with food-borne risk factors characterised by high hazard and pandemic risk, respectively. Overall, the net effect of information on food safety is negative. The reduction in premium prices ranges between 17.7% and 40.1% for label 'treated' and between 71.4% and 99.4% for label 'inspected', depending on the objective dimension of food safety. If a food-borne risk factor is objectively hazardous and risky, labels are ineffective in communicating the safety of a food product. The results suggest that when the price of information is higher as compared to the marginal expected benefit, consumers may rationally choose to remain imperfectly informed about food safety issues (Cao et al., 2015).

In order to corroborate our results, we quantify the effect of label information on food safety associated with food-borne risk factors, objectively least (i.e. low hazard and idiosyncratic risk) and most (i.e. high hazard and pandemic risk) dangerous[11]: the results are reported in table 7.

[Table 7]

The information on food safety conveyed through labels and WTP for food safety are positively correlated, however most of the estimated coefficients for labels lose statistical significance. The

[11] We also quantified the effect of information on food safety associated with food-born risk factors subjectively most hazardous and risky (i.e. unknown and dreadful): the results, omitted, reveal no variability in the index of WTP. We do not estimate the counterpart for least hazardous and risky (i.e. known and not dreadful), from a subjective perspective, due to the lack of data related to food-born risk factors known and perceived as not dreadful.

information on food safety may eventually eliminate premium prices for products carrying such labels if consumers become aware of the objective risk associated with the consumption of products potentially exposed to hazards and not ensuring, through labels, adequate levels of food safety (Britwum and Yiannaka, 2019).

Consumers WPT increases by 185.6% if a label informs that a certain product is treated against a food-borne risk factor characterised by low hazard and idiosyncratic risk but is reduced by 113.3% if the food-borne risk factor is objectively hazardous and risky. This evidence suggests a low usefulness of a specific label informing that a certain product is treated against a food-borne risk factor: indeed, premium prices tend to increase only on condition of objective food safety (low hazard and idiosyncratic risk), but not if the food-borne risk factor is more likely to occur with severe consequences.

Consumers are willing to pay 80.7% less for a product carrying a label ensuring traceability if the product is associated with food-borne risk factors both less likely to occur with limited consequences and more likely to occur with severe consequences. In addition, if food safety of a product is inspected by public or private third parties, the premium price for the inspected product is 123.7% lower if the food-borne risk factor associated with the consumption of that product is hazardous and risky. Furthermore, in considering the positive relationship between the labels and the premium price for food safety, the net effect is negative both for the labels 'traced' (-29.6%) and 'inspected' (-71.4%).

Lastly, we control for the effects of label information on food safety when the subjective perception of consumers equals the objective risk and hazard associated with a food-borne risk factor. Table 8 shows the results for food-borne risk factors unknown for consumers and characterised by high hazard or pandemic risk[12].

[Table 8]

[12] We do not estimate the counterpart for food-born risk factors characterised by high hazard or pandemic risk and perceived as dread by consumers, due to the lack of evidence in our sample.

The information on food safety, conveyed through labels 'treated', 'safe' and 'inspected', and premium prices for food safety are positively correlated, confirming previous results (see table 5). If food-borne risk factors unknown by consumers are characterised by high hazard or pandemic risk, the premium prices decrease by about 113.3-143.5% for a treated product and about 123.7-157.9% for an inspected product. As suggested in Cao et al. (2015), when being exposed to relevant risk information about food safety, consumers tend to increase their risk perception and decrease their WTP.

5. Concluding remarks

Food-borne infection causes considerable illness, heavily affecting healthcare systems. The risks in the food sector are many, of various nature and, potentially, responsible of direct and indirect costs (Gallo et al., 2020). Given the spread of food-borne infections, the assessment of food risks is a relevant issue for the food industry and for policymakers (Ververis et al., 2020). If food risks are numerous, and of a complex nature, the rationale guiding consumers' choices becomes challenging. The channels through which the information may be conveyed and the cognitive process guiding consumers in processing information are certainly factors that influence how consumers make decisions under uncertainty.

Following a systematic and meta-analytical approach, we evaluated how different sources and types of risks (i.e. objective and subjective) are perceived by the consumers, in order to investigate how the information on food risks may be efficiently communicated.

The results revealed that information on food safety, conveyed through labels, exerts a positive influence on premium prices for food safety. Consumers would be willing to pay a price premium of up to 168.7% for food products that are treated against a specific food-borne risk factor, certified to be safe, tested or inspected by public or third parties. Consider a meat-based product, ground beef with an average reference price of 4.22 USD/lb. The consumers may be willing to pay up to 11.34 USD/lb more for the same ground beef if it carried labels 'treated', 'safe' and 'inspected'.

We found that the positive effect of label information on food safety is almost nullified when we consider both objective and subjective risks. In fact, labels are inefficient vehicles of information on food safety, when products are likely to be affected by food-borne risk factors, objectively hazardous and risky. The net effect of label information on food safety is detrimental for premium prices. Not surprising, when the price of information is higher as compared to the marginal expected benefit, consumers may rationally choose to remain imperfectly informed about food safety issues (Cao et al., 2015). We derived similar conclusions for premium prices for products potentially exposed to unknown food risks perceived as dread by consumers. With uncertainty, consumers tend to interpret information according to their needs, thus inadequately selecting signals (Verbeke 2005).

Overall, the results suggest that, when exposed to relevant risk information about food safety, consumers tend to increase their risk perception and decrease their premium prices for information on food safety. Our evidence is in line with findings from Cao et al. (2015) and Britwum and Yiannaka (2019) who suggest that information about food safety may eventually eliminate premium prices for products carrying such labels, if consumers become aware of the objective risk associated with the consumption of products potentially exposed to hazards.

Our results have important implications for the food industry, as well as for policymakers and institutions. Food-borne factors are frequently characterised by asymmetric information. In several cases, the producers (or sellers) are better informed than consumers on food properties and potential food safety risk (Grunert, 2005). A remarkable example is the mismatch between the objective and the subjective risks associated with new technologies, as consumers may be not aware of scientific evidence. This mismatch tends to reduce with a wider dissemination of scientific evidence (Kemper et al., 2018). Using labels on safety information may contribute to lower the distance between (objective) scientific risks and (subjective) perceived risks, reducing inefficiencies arising from asymmetric information (Ortega et al., 2014). Nonetheless, correctly conveying the information is challenging and needs to be further deepened (Ritson and Mai, 1998). At the policy level, it is important that the information provided to consumers is representative of benefits, so to increase consumer confidence in information conveyed through labels (Britwum and Yiannaka, 2019) and prevent both food scares and diseases.

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Tables

Table 1. List of articles included in the quantitative analysis.

Reference	Journal	Rank[a]	Citations[b]	Country[c]	Product category	Food-borne risk factor
Boncinelli et al. (2018)	Agribusiness	Q2	0	ITA	Fish (local vs. no info)	Food safety
Britwum and Yiannaka (2019)	Food Policy	Q1	0	USA	Meat (local)	E. coli outbreak
Brooks and Lusk (2012)	Journal of Agricultural and Resource Economics	Q2	8	USA	Meat (local)	New technologies
Campbell and Doherty (2013)	European Review of Agricultural Economics	Q2	15	GBR	Meat (local)	Food safety
Carlucci et al. (2017)	Marine Resource Economics	Q2	12	ITA	Fish (local vs. imported)	Food safety
Enneking (2004)	European Review of Agricultural Economics	Q2	68	DEU	Meat (local)	Food safety
Fonner and Sylvia (2015)	Marine Resource Economics	Q2	24	USA	Fish (local vs. no info)	Mercury level
Glenk et al. (2012)	Food Policy	Q1	6	GBR	Beverage (local vs. no info)	Chemical contamination
Grebitus et al. (2013)	Food Policy	Q1	21	USA	Meat (local)	New technologies
Kemper et al. (2018)	Food Policy	Q1	0	USA	Meat (local vs. no info)	New technologies
Lewis et al. (2016)	Journal of Behavioral and Experimental Economics	Q2	10	USA	Sugar (imported)	New technologies
Lewis et al. (2017)	Journal of Agricultural Economics	Q1	14	GBR	Meat (local vs. imported)	E. coli outbreak, BSE crisis
Li et al. (2018)	Journal of Agricultural and Applied Economics	Q3	2	USA	Meat (local vs. imported)	Food safety
Lim and Hu (2016)	Canadian Journal of Agricultural Economics	Q2	16	CAN	Meat (local vs. imported)	BSE crisis
Lim et al. (2013)	Canadian Journal of Agricultural Economics	Q3	52	USA	Meat (local vs. imported)	BSE crisis
Loureiro and Umberger (2007)	Food Policy	Q2	293	USA	Meat (local vs. imported)	BSE crisis
Merritt et al. (2018)	Journal of Agricultural and Applied Economics	Q3	3	USA	Meat (local vs. no info)	Food safety
Ortega et al. (2014)	Agricultural Economics	Q2	13	USA	Fish (local vs. imported)	Food adulteration

Ortega et al. (2015)	Australian Journal of Agricultural and Resource Economics	Q2	7	USA	Fish (local vs. imported)	Food adulteration
Ortega et al. (2011)	Food Policy	Q1	161	CHN	Meat (local vs. no info)	Food safety
Owusu-Sekyere et al. (2018)	African Journal of Agricultural and Resource Economics	n.a.	0	GHA	Meat (local)	Food safety
Peterson and Burbidge (2012)	Journal of Agricultural and Resource Economics	Q2	3	JPN	Meat (local vs. imported)	BSE crisis
Savchenko et al. (2018)	Food Policy	Q1	4	USA	Fruit and vegetables (local)	Recycled water
Thai et al. (2017)	International Journal of Economic Research	Q2	0	VNM	Vegetables (local)	Chemical contamination
Tonsor (2011)	European Review of Agricultural Economics	Q1	35	USA	Meat (local vs. no info)	Food safety
Ubilava and Foster (2009)	Food Policy	Q1	55	GEO	Meat (local)	Food safety
Viegas et al. (2014)	Journal of Agricultural Economics	Q2	13	PRT	Meat (local)	Food safety
Wägeli et al. (2016)	International Journal of Consumer Studies	Q2	18	DEU	Dairy (local)	Dioxin contamination
Wolf et al. (2011)	Journal of Agricultural and Resource Economics	Q2	28	USA	Dairy (local vs. no info)	Food safety
Wongprawmas and Canavari (2017)	Food Policy	Q1	14	THA	Vegetables (local)	Food safety
Wu et al. (2017)	Agribusiness	Q2	6	CHN	Meat (local vs. no info)	Food safety
Wu et al. (2015a)	China Agricultural Economic Review	Q3	8	CHN	Meat (local vs. no info)	Food safety
Wu et al. (2015b)	China Economic Review	Q2	25	CHN	Meat (local vs. no info)	Food safety
Wu et al. (2020)	Journal of Agricultural Economics	Q1	0	CHN	Dairy (local)	Food safety
Xu et al. (2017)	Chinese Economy	Q2	0	CHN	Dairy (local vs. imported)	Melamine contamination
Yin et al. (2017)	China Agricultural Economic Review	Q3	6	CHN	Vegetables (local vs. imported)	Food safety
Yin et al. (2019)	Agribusiness	Q2	0	CHN	Vegetables (local vs. imported)	Food safety
Yin et al. (2018)	Canadian Journal of Agricultural Economics	Q2	1	CHN	Dairy (local vs. imported)	Melamine contamination

[a] Journal rank provided by the Scimago Journal & Country Rank (SJR) at the date of publication and referred to the subject area Economics, Econometrics and Finance. Q1, Q2 and Q3 stands for journals respectively in the 25^{th}, 50^{th}, 75^{th} percentiles, n.a. stands for not available.

[b] Number of citations collected from Scopus in July 12, 2019.

[c] Acronyms are Canada (CAN), China (CHN), Germany (DEU), United Kingdom (GBR), Georgia (GEO), Ghana (GHA), Italy (ITA), Japan (JPN), Portugal (PRT), Thailand (THA), United States (USA), Vietnam (VNM).

Table 2. Categorical variables for dimensions on food safety.

Dimension	Definition	Value of categorical variables		
		-1	0	1
Objective food safety				
Hazard	Severity of adverse consequences	Limited injurious (**low hazard**)	Baseline hazard	High injurious (**high hazard**)
Risk	Likelihood of occurrence	Low likelihood of occurrence (**idiosyncratic risk**)	Baseline risk	High likelihood of occurrence (**pandemic risk**)
Subjective food safety				
Concern	Known vs. unknown	Observable, immediate, old (**known**)	Baseline concern	Unobservable, delayed, new (**unknown**)
Awareness	Not dreadful vs. dreadful	Controllable, not global catastrophic, not fatal, voluntary (**not dreadful**)	Baseline awareness	Uncontrollable, global catastrophic, fatal, involuntary (**dreadful**)

Table 3. Analysis of premium prices for information on food safety.

Currency		Obs. (%)	WTP	Reference price	Deviation (%)
CNY		17.9	4.98	9.35	53.30
of which					
	Meat	60.9	5.52	12.57	43.92
	Dairy	30.4	5.07	5.00	101.32
EUR		25.3	3.31	2.96	111.76
of which					
	Meat	41.5	1.08	3.56	30.30
	Dairy	46.2	0.48	1.39	34.38
	Fish	12.3	21.42	6.79	315.56
GBP		7.8	1.69	4.73	35.66
of which					
	Meat	20.0	1.31	6.85	19.12
	Dairy	20.0	3.79	3.25	116.52
GEL		1.2	3.65	9.00	40.54
GHc		2.7	3.65	9.00	40.54
JPY		0.8	57.00	222.34	25.64
THB		1.2	21.73	50.00	43.46
USD		40.8	3.29	7.37	44.64
of which					
	Meat	55.2	4.43	7.70	57.49
	Dairy	23.8	1.20	7.20	16.72
	Fish	15.2	3.04	8.69	35.01
VND		2.3	10.47	10,000.00	0.10

Notes: Average values reported for willingness to pay (WTP) and reference prices, by currency. The percent deviation is computed as the ratio between WTP and reference price. Acronyms are Chinese Yuan (CNY), Euro (EUR), British pound (GBP), Georgian Lari (GEL), Ghana Cedi (GHc), Japanese Yen (JPY), Thailand Baht (THB), US Dollar (USD), Vietnam Dong (VND).

Table 4. Percentage of observations for combinations of risk-hazard and awareness-concern.

Dimensions of objective food safety

	Hazard			
Risk	Low	Baseline	High	Total
Idiosyncratic	42.6	4.0	0.0	46.6
Baseline	0.0	41.8	0.0	41.8
Pandemic	5.6	0.0	6.0	11.6
Total	48.2	45.8	6.0	100.0

Dimensions of subjective food safety

	Concern			
Awareness	Not dread	Baseline	Dread	Total
Known	0.0	0.0	4.0	4.0
Baseline	0.0	41.8	0.0	41.8
Unknown	39.8	0.0	14.4	54.2
Total	39.8	41.8	18.4	100.0

Notes: total observations are 251.

Table 5. Effects of information on food safety.

Explanatory variables	(1)	(2)	(3)	(4)
Treated	0.594***	0.627***	0.598**	0.714***
	(0.210)	(0.224)	(0.230)	(0.230)
Safe	0.495***	0.468**	0.553**	0.536**
	(0.185)	(0.196)	(0.225)	(0.222)
Inspected	0.375**	0.406**	0.429**	0.437**
	(0.177)	(0.181)	(0.200)	(0.196)
Traced	0.240	0.233	0.185	0.126
	(0.161)	(0.165)	(0.186)	(0.184)
Journal in 25^{th} percentile		-0.347	-0.208	-0.278
		(0.385)	(0.394)	(0.389)
Journal in 50^{th} percentile		-0.258	0.015	-0.415
		(0.377)	(0.404)	(0.422)
Journal in 75^{th} percentile		-0.448	-0.267	-0.332
		(0.393)	(0.419)	(0.412)
Grebitus C.			-0.206	-0.261
			(0.288)	(0.283)
Chen M.			-0.505	-0.133
			(0.355)	(0.371)
Hu W.			-0.026	0.056
			(0.195)	(0.194)
Olynk Widmar N.J.			-0.599**	-0.186
			(0.272)	(0.300)
Ortega D.L.			0.396	0.844
			(0.541)	(0.552)
Wang H.			-0.083	-0.620
			(0.402)	(0.434)
Wu L.			0.147	0.101
			(0.394)	(0.387)

Zhu D.			-0.462	-0.037
			(0.537)	(0.546)
Agricultural and Biological Sciences				-0.634***
				(0.211)
Constant	0.285**	0.587	0.501	1.153**
	(0.124)	(0.392)	(0.407)	(0.455)

Notes: Ordinary Least Square (OLS) estimation of the equation (4). The dependent variable is the index of willingness to pay (WTP) for information on food safety. The explanatory variables are modelled as dummy variables. Column (1) is the basic specification; control factors added in following specifications: dummies for journal rank in column (2), dummies for influential authors in column (3), dummy for journal area in column (4). Observations are 251. Standard errors are in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

Table 6. Effects of information on food safety associated with food-borne risk factors characterised by high hazard (1), pandemic risk (2), unknown (3), perceived as dreadful (4).

	Objective dimensions of food safety		Subjective dimensions of food safety	
Explanatory variables	High hazard (1)	Pandemic risk (2)	Unknown (3)	Dread (4)
Treated	0.956***	1.034***	1.194***	0.836***
	(0.253)	(0.257)	(0.227)	(0.246)
Safe	0.521**	0.605**	0.186	0.647***
	(0.228)	(0.259)	(0.353)	(0.221)
Inspected	0.523**	0.585***	0.566*	0.351
	(0.205)	(0.210)	(0.336)	(0.222)
Traced	0.110	0.154	0.606*	0.171
	(0.187)	(0.190)	(0.355)	(0.191)
Treated * food safety dimensions	-1.133**	-1.435***	Omitted	No
	(0.560)	(0.535)		
Safe * food safety dimensions	No	-0.174	0.545	No
		(0.491)	(0.514)	
Inspected * food safety dimensions	-1.237*	-1.579**	-0.717	0.345
	(0.683)	(0.663)	(0.468)	(0.470)
Traced * food safety dimensions	No	No	-1.122***	-0.305
			(0.426)	(0.479)

Notes: Ordinary Least Square (OLS) estimation of the equation (4). The dependent variable is the index of willingness to pay (WTP) for information on food safety. The explanatory variables are modelled as dummy variables. Constant and control factors (food safety dimensions, journal rank, influential authors, journal area) included in all specifications. No data available for 'safe * high', 'traced * high', 'traced * pandemic', 'treated * dread, 'safe * unknown'. 'treated * unknown' omitted due to collinearity. Observations are 251. Standard errors are in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 7. Effects of information on food safety associated with food-borne risk factors objectively least (1) and most (2) dangerous.

Explanatory variables	Extreme dimensions of objective food safety	
	Low hazard & idiosyncratic risk	High hazard & pandemic risk
	(1)	(2)
Treated	-0.257	0.956***
	(0.396)	(0.253)
Safe	0.258	0.521**
	(0.238)	(0.228)
Inspected	0.310	0.523**
	(0.248)	(0.205)
Traced	0.511*	0.110
	(0.272)	(0.187)
Treated * food safety dimensions	1.856***	-1.133**
	(0.463)	(0.560)
Safe * food safety dimensions	No	No
Inspected * food safety dimensions	-0.092	-1.237*
	(0.418)	(0.683)
Traced * food safety dimensions	-0.807**	No
	(0.351)	

Notes: Ordinary Least Square (OLS) estimation of the equation (4). The dependent variable is the index of willingness to pay (WTP) for information on food safety. The explanatory variables are modelled as dummy variables. Constant and control factors (food safety dimensions, journal rank, influential authors, journal area) included in all specifications. No data available for 'safe * low * idiosyncratic', 'safe * high * pandemic', 'traced * high * pandemic'. Standard errors are in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 8. Effects of information on food safety when objective risk equals subjective risk.

	Extreme dimensions of objective and subjective food safety	
Explanatory variables	High hazard & unknown	Pandemic & unknown
Treated	0.956***	1.034***
	(0.253)	(0.257)
Safe	0.521**	0.605**
	(0.228)	(0.259)
Inspected	0.523**	0.585***
	(0.205)	(0.210)
Traced	0.110	0.154
	(0.187)	(0.190)
Treated * food safety dimensions	-1.133**	-1.435***
	(0.560)	(0.535)
Safe * food safety dimensions	No	-0.174
		(0.491)
Inspected * food safety dimensions	-1.237*	-1.579**
	(0.683)	(0.663)
Traced * food safety dimensions	No	No

Notes: Ordinary Least Square (OLS) estimation of the equation (4). The dependent variable is the index of willingness to pay (WTP) for information on food safety. The explanatory variables are modelled as dummy variables. Constant and control factors (food safety dimensions, journal rank, influential authors, journal area) included in all specifications. No data available for 'safe * high * unknown', 'traced * high * unknown', 'traced * pandemic * unknown'. Standard errors are in parentheses.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Appendix

Table A.1. Descriptive statistics for main explanatory variables.

Variable	Description	Mean	Std. Dev.
Labels			
Treated	1 if label is Treated (0 otherwise)	0.112	0.315
Safe	1 if label is Safe (0 otherwise)	0.171	0.378
Inspected	1 if label is Inspected (0 otherwise)	0.203	0.403
Traced	1 if label is Traced (0 otherwise)	0.307	0.462
Labels with high hazard			
Treated * high	1 if label is Treated and hazard is high (0 otherwise)	0.024	0.153
Safe * high[§]	1 if label is Safe and hazard is high (0 otherwise)	0.000	0.000
Inspected * high	1 if label is Inspected and hazard is high (0 otherwise)	0.012	0.109
Traced * high[§]	1 if label is Traced and hazard is high (0 otherwise)	0.000	0.000
Labels with pandemic risk			
Treated * pandemic	1 if label is Treated and risk is pandemic (0 otherwise)	0.024	0.153
Safe * pandemic	1 if label is Safe and risk is pandemic (0 otherwise)	0.036	0.186
Inspected * pandemic	1 if label is Inspected and risk is pandemic (0 otherwise)	0.012	0.109
Traced * pandemic[§]	1 if label is Traced and risk is pandemic (0 otherwise)	0.000	0.000
Labels with unknown food-borne risk factor			

Treated * unknown	1 if label is Treated and food-borne risk factor is unknown (0 otherwise)	0.112	0.315
Safe * unknown	1 if label is Safe and food-borne risk factor is unknown (0 otherwise)	0.036	0.186
Inspected * unknown	1 if label is Inspected and food-borne risk factor is unknown (0 otherwise)	0.080	0.271
Traced * unknown	1 if label is Traced and food-borne risk factor is unknown (0 otherwise)	0.147	0.355
Labels with dread food-borne risk factor			
Treated * dread[§]	1 if label is Treated and phenomena is dread (0 otherwise)	0.000	0.000
Safe * dread[§]	1 if label is Safe and phenomena is dread (0 otherwise)	0.000	0.000
Inspected * dread	1 if label is Inspected and phenomena is dread (0 otherwise)	0.072	0.259
Traced * dread	1 if label is Traced and phenomena is dread (0 otherwise)	0.064	0.245
Labels with high hazard and pandemic risk			
Treated * high * pandemic	1 if label is Treated, hazard is high, risk is pandemic (0 otherwise)	0.024	0.153
Safe * high * pandemic[§]	1 if label is Safe, hazard is high, risk is pandemic (0 otherwise)	0.000	0.000
Inspected * high * pandemic	1 if label is Inspected, hazard is high, risk is pandemic (0 otherwise)	0.012	0.109
Traced * high * pandemic[§]	1 if label is Traced, hazard is high, risk is pandemic (0 otherwise)	0.000	0.000
Labels with unknown and dread food-borne risk factor			
Treated * unknown * dread[§]	1 if label is Treated and food-borne risk factor is unknown, dread (0 otherwise)	0.000	0.000
Safe * unknown * dread[§]	1 if label is Safe and food-borne risk factor is unknown, dread (0 otherwise)	0.000	0.000
Inspected * unknown* dread	1 if label is Inspected and food-borne risk factor is unknown, dread (0 otherwise)	0.068	0.252
Traced * unknown * dread	1 if label is Traced and food-borne risk factor is unknown, dread (0 otherwise)	0.028	0.165
Labels with low hazard and idiosyncratic risk			

Treated * low * idiosyncratic	1 if label is Treated, hazard is low, risk is idiosyncratic (0 otherwise)	0.088	0.283
Safe * low * idiosyncratic§	1 if label is Safe, hazard is low, risk is idiosyncratic (0 otherwise)	0.000	0.000
Inspected * low * idiosyncratic	1 if label is Inspected, hazard is low, risk is idiosyncratic (0 otherwise)	0.068	0.252
Traced * low * idiosyncratic	1 if label is Traced, hazard is low, risk is idiosyncratic (0 otherwise)	0.147	0.355
Labels with known and not dread food-borne risk factor§			
Treated * known * not dread	1 if label is Treated and food-borne risk factor is known and not dread (0 otherwise)	0.000	0.000
Safe * known * not dread	1 if label is Safe and food-borne risk factor is known and not dread (0 otherwise)	0.000	0.000
Inspected * known * not dread	1 if label is Inspected and food-borne risk factor is known and not dread (0 otherwise)	0.000	0.000
Traced * known * not dread	1 if label is Traced and food-borne risk factor is known and not dread (0 otherwise)	0.000	0.000
Labels with high hazard and unknown food-borne risk factor			
Treated * high * unknown	1 if label is Treated, hazard is high, food-borne risk factor is unknown (0 otherwise)	0.024	0.153
Safe * high * unknown§	1 if label is Safe, hazard is high, food-borne risk factor is unknown (0 otherwise)	0.000	0.000
Inspected * high * unknown	1 if label is Inspected, hazard is high, food-borne risk factor is unknown (0 otherwise)	0.012	0.109
Traced * high * unknown§	1 if label is Traced, hazard is high, food-borne risk factor is unknown (0 otherwise)	0.000	0.000
Labels with pandemic risk and unknown food-borne risk factor			
Treated * pandemic * unknown	1 if label is Treated, risk is pandemic, food-borne risk factor is unknown (0 otherwise)	0.024	0.153
Safe * pandemic * unknown	1 if label is Safe, risk is pandemic, food-borne risk factor is unknown (0 otherwise)	0.036	0.186
Inspected * pandemic * unknown	1 if label is Inspected, risk is pandemic, food-borne risk factor is unknown (0 otherwise)	0.012	0.109
Traced * pandemic * unknown	1 if label is Traced, risk is pandemic, food-borne risk factor is unknown (0 otherwise)	0.000	0.000
Labels with high hazard and dread food-borne risk factor§			

Treated * high * dread	1 if label is Treated, hazard is high, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Safe * high * dread	1 if label is Safe, hazard is high, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Inspected * high * dread	1 if label is Inspected, hazard is high, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Traced * high * dread	1 if label is Traced, hazard is high, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Labels with pandemic risk and dread food-borne risk factor[§]			
Treated * pandemic * dread	1 if label is Treated, risk is pandemic, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Safe * pandemic * dread	1 if label is Safe, risk is pandemic, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Inspected * pandemic * dread	1 if label is Inspected, risk is pandemic, food-borne risk factor is dread (0 otherwise)	0.000	0.000
Traced * pandemic * dread	1 if label is Traced, risk is pandemic, food-borne risk factor is dread (0 otherwise)	0.000	0.000

[§] indicates explanatory variables with no observations.