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MISASSESSED RISK IN CONSUMER VALUATION OF FOOD SAFETY: AN EXPERIMENTAL APPROACH

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Introduction

Recent outbreaks of food-borne pathogens have focused the attention of consumers and regulators on the issue of food safety, typically with an emphasis on understanding the demand for safer food. Despite efforts by government agencies and private firms to ensure that food is safe, some products contain bacteria, parasites, fungi and viruses that, when consumed, lead to illness. Currently, more than 40 different food-borne microbial pathogens are known to cause sickness in humans (Buzby *et al.*, 2001). With incidences of such illnesses imposing significant costs on countries' food marketing and health care systems, food safety has emerged as a very serious policy issue.

Individuals' attitudes and beliefs shape their perceptions of food safety risk. In turn, risk perceptions affect consumers' willingness to pay for food safety improvements. Yet, this relationship is difficult to generalize.[1] Risk-related behavioural research suggests that individuals overestimate the likelihood of low-probability events, while under-assessing the likelihood of high-probability events (Lichtenstein *et al.*, 1978). However, these biases are poorly understood in terms of food safety risks. Consumers' difficulty in risk appraisal and tendency to misassess low-probability risks motivate the need to expand the research framework to include the concept of risk perceptions.

The objective of this study is to estimate the value that Canadians place on improvements in food safety, while investigating the presence of systematic misassessments of food safety risk by consumers. This is accomplished using an

[1] The nonmarket nature of food safety complicates consumers' valuation decisions, and researchers' ability to evaluate it, since safety is an implicit and often invisible characteristic of food products.

experimental auction design, with two explicit risk reductions and a mid-way release of objective risk information to allow for identification of these misassessments.

Consumer risk-related decisions require some assessment of risk, yet objective information is seldom available. Instead, consumers develop subjective risk probabilities based on their perceptions of the hazard. Since consumer preferences reflect their perceptions, a modified expected utility framework can be used to understand the income-risk tradeoff and marginal willingness to pay for risk reductions. Nevertheless, few previous studies have incorporated the effects of consumers' risk perceptions into the valuation framework (Eom, 1995).

While several measurement techniques exist, experimental auctions create nonhypothetical environments in which to examine consumer choices. The laboratory auction setting enables economic researchers to identify, isolate and understand how consumers trade money for reduced risk. Although risk cannot be eliminated, it can be managed and minimized through tradeoffs. While individuals face tradeoffs in many parts of their lives, including tastes and aestethics, the focus of this study is the tradeoff between dollars and risk. A risk-dollar tradeoff implies that an individual is aware of both the risk and the opportunity to mitigate risk. Information about the nature of risk is required for an unbiased assessment of tradeoffs. Ideally, extensive experimental evidence would support individuals' decisions regarding the probabilities of risks. Instead, subjective assessments are relied upon for practical decision-making. The decision process is not straightforward, however, as individuals must also consider budgetary constraints in the food safety tradeoff. Efficiency in tradeoffs requires that individuals

think systematically about risks, yet decisions under uncertainty are notoriously difficult to make (Viscusi *et al.*, 1986).

Conceptual Model

Risk-averse individuals may be willing to pay a premium to avoid a risky event. In a lottery with money, risk-averse individuals may choose to forgo a portion of certain wealth to avoid a gamble with an equivalent expected value. In the case of food safety, wealth may be considered as not only monetary wealth, but also non-monetary factors like time and health. Sickness from food-borne illness reduces a person's physical health, but also leads to wealth losses through lost wages due to absence from employment and time spent undergoing medical treatment. It follows, then, that risk-averse consumers may choose to forgo some portion of their monetary wealth to avoid the food safety "gamble", which could affect their overall wealth.

Jones-Lee (1974) outlines a conceptual framework, later adapted by Smith and Desvousges (1987), that demonstrates the maximum an individual will pay for a risk change.[2] Jones-Lee recognizes the subjective nature of risk, and presents subjective probabilities as the most relevant concept for the context.[3] Specifically, in a two-state world, an individual faces probabilities p of sickness (state S) and (1-p) of health (state H). Typically, health is preferred to sickness. Individuals' utility functions are state-dependent and functions of wealth W. Individuals act to maximize expected utility (EU), where:

[2] While Jones-Lee modelled life and death as states of the world, in the case of food safety, the two relevant states are sickness and health.

[3] Jones-Lee (1974) suggests that, since it is unlikely that individuals view their own deaths or injury as the subject of repeated experiments, preconditions for objective risk probability based on relative frequency are not fulfilled.

(1) $EU = (1-p)H(W) + pS(W)$

where $H(W)$ is the utility of wealth associated with health and $S(W)$ is the utility of wealth associated with sickness. Utility functions $H(W)$ and $S(W)$ are continuous, unique up to the same linear transformation, and at least twice-differentiable. Individuals are assumed to prefer more to less (wealth) and to be financially risk averse.

Suppose an individual has wealth ($\overline{W} > 0$) and faces probability $\overline{p}$, where $0 < \overline{p} < 1$, of sickness, expected utility is then given by:

(2) $EU = (1-\overline{p})H(\overline{W}) + \overline{p}S(\overline{W})$.

Now suppose that the individual has the opportunity to reduce the probability of sickness from $\overline{p}$ to p. Given the restrictions, an individual will forfeit a positive amount, *V*, in exchange for the lower probability of death. The maximum amount he will give up must leave him with the same level of expected utility as initially experienced. The *V* is determined by solving the following equality for *V*:

(3) $(1 - p)\, H\,(W - V, \mathbf{Z}) + p\, S\,(W - V, \mathbf{Z}) = (1 - \overline{p})\, H\,(W, \mathbf{Z}) + \overline{p}\, S\,(W, \mathbf{Z})$

where **Z** is a vector of socio-demographic variables.[4]

Jones-Lee establishes the general form of the functional relationship of probability and payment, *V*(*p*), depicted with the solid curve-linear relationship between *V* and *p* (Figure 1). *V* is positive for values of *p* less than $\overline{p}$ (paying for an increase in safety), and

[4] Similarly, if the individual accepts an increase in probability of sickness, the minimum amount he requires as compensation will increase his wealth to where the higher probability and wealth also satisfy condition (3).

negative for values of p more than $\overline{p}$ (demanding compensation for decreased safety).[5] The marginal value of a decrease in risk from the initial risk level is $-\partial V/\partial p$, and can be shown to increase with both initial risk and initial wealth.[6]

In Jones-Lee's expected utility model context, willingness-to-pay values reflect individuals' assessment of both initial risk and reduced risk. If participants initially perceive food safety risk to be lower than the objective level, then their bids should increase once aware of the magnitude of the threat. Conversely, if food safety risk is initially overestimated, bids will decrease once objective risk estimates have been announced. Figure 1 illustrates patterns in willingness-to-pay values (V) based on initial risk levels ($\overline{p}_i$) and reduced risk levels (p_i), where $i \in \{t,u,o\}$, t is threshold risk, u is underestimated and o is overestimated risks (relative to the threshold). Threshold levels are baseline risk levels defined as "typical" by experts. Since the function V depends on p, differences in perceptions of p result in different curves. For illustrative purposes, $\overline{p}_t$ and p_t represent typical and reduced threshold risk levels, respectively. The reductions from $\overline{p}_i$ to p_i are shown as equal in each case to ease comparison. In the case of an underestimation of risk, perceived $\overline{p}_u$ and p_u are to the left of the threshold values, as is the function V. Once aware of the perceptual error in assessing the risk levels of the products, individual's willingness to pay increases from V_u to V_t. Overestimation is depicted by $\overline{p}_o$ and p_o to the right of the threshold (as is the function V), and is reflected

[5] The behaviour of $V(p)$ as p approaches zero or unity reflects the individual's attitudes towards extreme safety and danger.

[6] The marginal value of a decrease in risk is $-(\partial V)/\partial p$ and is positive. The marginal value of an increase in risk is $(\partial V)/\partial p$ and is consequently negative.

by initially higher willingness-to-pay, V_o. When new risk information is incorporated into the individuals' perceptions, willingness-to-pay decreases from V_o to V_t.

These scenarios assume that objective information is partially or completely integrated into individual perceptions of food safety risk, and that individual willingness-to-pay adjusts to reflect new information. Failure to identify statistical differences between informational stages may indicate that information corresponds to naïve perceptions, or that it has not been assimilated into individual perceptions. In fact, this is a simplification of the risk assessment process, as the qualitative nature of risk is complex and difficult to characterize. The severity of negative consequences and the degree of personal control are among the issues consumers may consider in their decision-making.

Although overestimation is expected for low-probability risks, there is little *a priori* understanding of what events actually qualify as "low-probability". While it seems likely that illness due to food-borne pathogens represents a low-probability event, whether individuals perceive it as such is an empirical question. Several hypotheses emerge from the model. Willingness-to-pay values for reductions in risk are hypothesized to be positive for risk-averse individuals. Moreover, for concave utility functions with both total and marginal utility of income in the healthy state exceeding their respective values in the sickness state, marginal willingness-to-pay values for risk reductions are expected to be larger for higher initial risk levels. Characteristics relating to risk perceptions are expected to influence willingness-to-pay.

Consumers' perceptions may develop from available information, knowledge, experience and environmental factors, as well as personal characteristics, social and

cultural background. Most biases are due to systematic, incorrect assessment of probabilities. For example, low-probability events tend to be overestimated by individuals, while higher-probability events are generally underestimated. These perceptual errors, in turn, affect how individuals make choices under uncertainty.

Experimental Model

Indirect evidence, such as expenditure on services or related goods, or direct stated preference information gathered by surveys, may be used to estimate non-market values (Buzby *et al*., 1998). These methods have been used to value food safety, but are subject to significant limitations. Surveys lack market disciplines, like budget constraints and substitutes, while little is known about consumers' characteristics, information set or prior beliefs in a real market setting (Shogren *et al*., 1999). Experimental auctions create non-hypothetical market setting in which participants bid on and purchase products with specific attributes. They draw strength from both direct and indirect approaches, creating market scenarios with real choices. Although still facing certain limitations, laboratory auctions motivate participants to reveal their true preferences for different products and have emerged as a useful economic tool for non-market valuation (Fox *et al*., 1996).

Consumers' values for explicit food safety changes can be considered from two perspectives: willingness to pay for relatively safer food product and willingness to accept a product with a defined level of risk relatively higher than other products. Consistent empirical evidence reveals a divergence in values of the two approaches, despite economic theory suggesting willingness-to-pay and willingness-to-accept values should be equivalent or fall within a tight bound when income effects are low (Shogren *et al.*,

1994). Substitution effects are deemed responsible for the divergence; divergence expands as the degree of substitution decreases. For private non-market goods without close substitutes, divergence is robust and persistent. In the case of food safety, markets are incomplete; health cannot be perfectly exchanged for money. The nature of our food safety valuation research makes a willingness-to-pay approach more suitable than willingness-to-accept, as consumers indeed face budget constraints in the market, and must integrate income limitations into real purchasing decisions. Since individuals generally resist assuming increased involuntary, physical risks, the willingness-to-accept format could induce protest bidding (*i.e.*, zero bids not reflecting the value of risk or budget limitations).[7]

Experimental auction techniques have been used to estimate values for characteristics of various food products (Melton *et al.*, 1996; Roosen *et al.*, 1998; Lusk *et al.*, 2001a, 2001b). Previous experimental auctions for food safety improvements have used information about *Salmonella*, *E. Coli*, *Staphylococcus aureus*, *Trichinella spiralis* and *Clostridrium perfringens* for their pathogen descriptions (Hayes *et al*., 1995; Fox *et al.*, 1995,1996; Buzby *et al.* 1998). Risk perception research suggests that individuals generally overestimate low-probability risks, yet results for the studies involving *Salmonella* risk were inconsistent with this tendency.[8] Hayes *et al.* (1995) and Fox *et al.* (1996) report that participants initially underestimated the risk of *Salmonella* contamination. Participants, however, overestimated other pathogen risks. Hayes *et al.*

[7] Willingness-to-pay approaches may prompt some participants to bid to the budget constraint, an action analogous to the zero protest bid in willingness-to-accept studies.
[8] This inconsistency motivates the question of whether the odds presented in the experiments are sufficiently low to induce overestimation.

suggest that this pattern of incorrect assessments may be due to the fact that individuals do not understand the nature of food-borne illness. Results consistently indicate participants' willingness to pay a premium for lower-risk foods.

Previous experimental auctions involving food have used several different sealed-bid auction types. Second-price sealed-bid auctions, known as Vickrey auctions, have useful theoretical properties (McAfee and McMillan, 1987). The participant with the *highest* bid is declared the winner, but pays the *second-highest* price. A bidder's dominant strategy is to reveal his true willingness-to-pay value for explicit increases in food safety, regardless of how rivals behave. Kagel (1995) notes that the dominant strategy for second-price sealed-bid auctions is independent of the number of bidders, their risk attitudes, or the distribution from which their private values are drawn.

Previous applications of laboratory auction techniques (see Fox *et al.*, 1995 and Shogren *et al.*, 1994) provide guidance for the auction procedure designed to elicit consumers' willingness-to-pay for reductions in food safety risk. Two explicit risk reductions were used, broken into two treatments across 12 replications. The two-treatment design allows for the evaluation of both absolute and marginal values for risk reductions. In the first treatment (Replications 1 to 6), the risk reduction related to the chance of becoming ill from *Campylobacter* after consuming the food, and was from an initial risk of 1 in 75,000 to 1 in 100,000. In the second treatment (Replications 7 to 12), the risk was reduced from 1 in 100,000 to 1 in 125,000 probability of becoming ill.

Although *Salmonella* may be more familiar to food consumers, *Campylobacter* is

a more common food-borne pathogen (CDC).[9] Chicken consumption is reported as the dominant risk factor associated with illness from *Campylobacter*, selected for this study because of its prevalence and relatively unfamiliarity. "Objective" risk levels for the product descriptions were based on U.S. data from the Centre for Disease Control available in Bennett *et al.* (1987). An estimated 2,100,000 cases of Campylobacteriosis occur in the United States annually, suggesting an annually probability of infection of 1 in 114.[10] If an individual eats three meals per day every day of the year, the probability that any meal will result in illness is 1 in 125,143. The probability of contamination of the highest level of safety was represented in the auction by this objective level, ensuring that participants were not induced to take on risks they otherwise would not have assumed. The risk level increments were chosen to provide participants with products with understandable and significant differences in food safety characteristics. While the concept of marginal value refers to a small change in the level, small changes may be difficult for participants to understand in the experimental setting.

While previous experimental auctions for food safety used groups of undergraduate students (Fox *et al.*, 1995, 1996; Hayes *et al.*, 1995; Buzby *et al.*, 1998; Lusk *et al.*, 2001b), a wider range of students and members of the university community was sought.[11] Participants were recruited in person on the University property and through information signs posted across campus. A maximum of fifteen individuals participated in

[9] Campylobacteriosis, one of the most common causes of bacterial diarrhea, is transmitted to humans primarily through the consumption of contaminated animal meat products (Franco and Williams, 2001).
[10] To calculate the annual probability of infection, the incidence estimate was deflated by a population value of 240 million.
[11] Initial efforts to recruit participants from the community-at-large were abandoned due to time and budgetary constraints.

each auction, with different subjects for each of replication.

A practice auction was used to familiarize participants with auction procedures. This practice consisted of five rounds of bidding to upgrade from one type of chocolate bar to a different chocolate bar (subjects were given a $2 incentive for the practice round). Participants' questions were fielded throughout the practice rounds. The following steps were followed for each of the actual auctions:

a) Participants were given bidding cards marked with an identification number, a plain chicken sandwich, identified as Product A, and $20.
b) The product being auctioned was presented and identified as Product B. Participants received written descriptions of the products, describing risk in Product A and B as "typical" and "lower-than-typical", respectively (see product descriptions in Appendix). Probabilities of illness from consumption were not presented at this stage.
c) Sealed bids were solicited from participants to upgrade from Product A to Product B. At the end of each round of bidding, the highest bidder's identification number and the second-highest bid price were posted at the front of the room. Ten rounds of bidding were conducted to elicit participants' naïve values for improved food safety.
d) After the tenth round of bidding, additional information about Products A and B was presented to the participants orally and in writing. For Replications 1 to 6, participants were told that the chances of becoming ill from consuming Products A and B were 1 in 75,000 and 1 in 100,000, respectively. For Replications 7 to 12, the risk from Product A was stated as 1 in 100,000 and Product B's risk was given as 1 in 125,000. Participants were also given a brief description of the symptoms of

Camplyobacteriosis and the actual annual individual chance of illness (see the treatment details in the Appendix). Bids were then solicited for Rounds 11 to 20.

e) After the final round of bidding, a number between one and 20 was chosen at random. Random selection of the binding round assured that each round was as important as the next from participants' perspectives, and obviates endowment effects in subsequent rounds of bidding. The overall winner's identification number was announced, the payment was collected and their chicken product was exchanged for Product B. To fulfill the non-hypothetical aspect of the experiment, participants consumed their chicken product.

After the food-safety auction, participants were asked to complete a questionnaire designed to gather demographic, risk-related and experiential information.[12] Participants were asked not to discuss their auction experiences until all auctions had been staged.

Data

The auctions were staged over four weeks, with daytime and evening sessions scheduled to accommodate participants with different availability. In total, 166 individuals participated in the auctions: 81 in Treatment 1 and 85 in Treatment 2. Table 1 profiles the demographic information collected from participants. The sample was approximately split between men and women. The majority of participants were young adults; 140 were between the ages of 18 and 24 years. Education levels ranged from less than high school to post-graduate studies.

Table 2 lists the mean bids across participants by replication. Since six or seven

[12] Auctions questionnaires and other materials are available from the authors by request.

rounds are almost always necessary to generate demand-revealing behaviour (Coursey, 1987), statistics are presented for the complete stages (Rounds 1 to 10 and 11 to 20), and the four final, stabilized rounds of the stages (Rounds 7 to 10 and 17 to 20). To identify potential outliers, standardized Z-scores and boxplots were generated for the various mean values for each individual. Since one individual was flagged as extreme by both Z-scores and boxplots, further examination of this participant was merited. An erratic bidder, the participant's behaviour suggests an overall disregard for the experiment. Retention of the bidder may result in statistical distortion, and his elimination from the sample is justified. Six other individuals identified in Treatment 1 appear as statistical outliers, but their exclusion is less justified in the experimental context. These bidders may represent a segment of the population, those more sensitive to food safety issues and willing to pay more for risk reductions, and will be retained in the dataset to ensure its generality.

Normality is a fundamental assumption of parametric statistical analysis, as variation from a normal distribution may weaken the reliability of F- and t-statistics. Examination of distributions of all bids reveals a departure from normality, confirmed by Kolmogorov-Smirov (K-S) tests where the null hypotheses of normality are rejected with 99 per cent confidence.[13] Testing distributions of differences in mean bids by treatment (Rounds 11 to 20 and Rounds 1 to 10, and Rounds 17 to 20 and Rounds 7 to 10 for each individual) also leads to the rejection of the null hypotheses of normality.[14] Skewness and kurtosis are other patterns that identify non-normality.[15] Generally, skewness and kurtosis

[13] K-S-statistics are 0.158 (p-value=0.000) and 0.207 (p-value=0.000) for Treatments 1 and 2, respectively.
[14] K-S statistics are 0.096 (p-value=0.061) and 0.163 (p-value=0.000) for Treatments 1 and 2, respectively.
[15] According to the method used here, normal distributions have skewness and kurtosis statistics of 0.

values above 1 are considered problematic (Hair *et al.*, 1998, p. 72). Three of the four skewness values fall below this threshold, yet kurtosis appears in the four distributions as an abundance of bid values falling around zero. While transformations are available to correct for skewness and to reduce kurtosis, the directions of skewness and the types of possible remedies vary across cases. A given transformation may reduce nonnormality for one distribution while accentuating it for others. Transformations were not attempted, as they would likely have failed to improve the normality of the dataset.

Visual inspection of the data suggests that the distributions would be relatively normal if the large number of zeros were not present. Instead, their presence causes non-normality and has the potential to weaken the reliability of parametric tests contingent on normality. However, since nonparametric tests are robust to non-normality, results of both parametric and nonparametric tests are presented.[16]

Discussion of the results are divided in four sections, comparing bids across informational stages and treatments, and estimating willingness-to-pay values for the food safety risk reductions.

Differences in Informational stages - Treatment 1

Examining the patterns of bids elicited from auction participants can identify possible biases in food safety risk perceptions, as well as in the over- or underestimation of probabilities of illness. To test for informational effects, and to identify misassessments of food safety risk levels, differences in the mean bids in the informed and naïve rounds are tested. This test is based on the full data set (*i.e.*, mean bids from all informed and naïve

[16] See Conover (1999) for specific details of the tests used.

rounds) and the stabilized rounds (i.e., rounds 7 to 10 and 17 to 20). Rejection of the null hypotheses of no differences across informational stages implies that participants reconsidered their risk reduction valuation decision upon receiving information about objective pathogen risk levels and symptoms of illness. The information provided after the 10th round may have influenced individuals' perceptions of food safety risk. Figure 2 shows the average bids for the replications in the first treatment.

Table 3 summarizes the results of the parametric and nonparametric testing. Wilcoxon signed-rank (WSR) test uses the magnitude and sign of the differences to test for differences in means.[17] Note that a WSR test statistic less than zero and based on negative ranks is analogous to a positive t-test statistic. Examining the auction groups individually, statistically significant differences between informational stages are found for three of the six replications. In Replications 2, 4, and 5, the mean bids increased when information about the pathogen risk was released to participants, and the differences are significant, suggesting an initial underestimation in the pathogen risk. On average, participants in the naïve rounds of these auctions perceived the pathogen risk to be less likely than the threshold levels presented after Round 10. While test statistics are negative (WSR is negative in interpretation) for Replication 1, they are not statistically significant. Test statistics for Replications 3 and 6 are positive but not statistically significant.

Before testing for differences in the means from the entire treatment, the statistical appropriateness of pooling Replications 1 through 6 is tested. Levene's test, a parametric

[17] WSR test assumes the symmetry of the distribution of differences. A previous discussion of normality identified skewness for only one of four cases and visual inspection suggests that the distributions are indeed reasonably symmetric. As such, the WSR is used for this analysis.

procedure, tests the null hypothesis of homogeneous variances. The Kruskal-Wallis (K-W) test examines differences in distributional locations, while assuming that all samples are independent. Table 4 summarizes the results, which indicate that the null hypotheses of samples from an identical population are rejected if all replications are included in Treatment 1.

Visual inspection of Figure 2 shows Replications 4 and 5 as distinct from the other auctions; the magnitude of the bids in these auctions fall above and below, respectively, the means of other replications in Treatment 1. As expected, omission of these replications from the treatment yields results that do not lead the rejection of the null hypotheses of homogeneous variances and identical distribution functions. Yet, the research value of excluding these auctions is questionable; while these replications may be statistically aberrant, they provide interesting behavioural information. In Replication 4, several participants engaged in a bidding war, escalating the price in each subsequent round. Auction monitors observed no unusual behaviour, as participants appeared to be vying in earnest for the auctioned product. Replication 5 involved several individuals who bid very low.[18] Their inclusion in the dataset, while not remarkable on a treatment level, lowers the mean bids for that particular replication. To eliminate these replications is to lose valuable experimental information – the trade-off of statistical strength and behavioural information value is apparent. While further testing has been included for all replications and the censored treatment (Replications 1, 2, 3, and 6), the issue of lost

[18] Two of the 12 participants placed zero bids across all rounds, while another participant's bids averaged only $0.07 across the 20 rounds.

behavioural information must not be overlooked. Nevertheless, to allow for differences in the analysis with and without the aberrant replications, tests are conducted with all replications and with only Replications 1, 2, 3 and 6.

Table 5 presents the results of tests for significance differences across informational stages for Treatment 1. When all replications in Treatment 1 are examined, there are statistically significant differences between naïve and informed stages of the experimental auctions. The release of information appears to induce an increase in mean bids (positive t-statistics and negative WSR statistics based on negative ranks). Participants were given information not only about the threshold odds of illness, but a short description of the symptoms of illness due to *Campylobacter*. While there is evidence that individuals may assess the frequency of events by the ease with which examples of occurrences can be conjured (Tversky and Kahneman, 1982), this phenomenon, described as the availability heuristic, is assumed to be small in this case. Individuals tend to be familiar with the effects of mild food-poisoning, and it is reasonable to proceed as though individuals were responding primarily to the probability information.

Results suggest that participants initially underestimated the likelihood of contracting *Campylobacter* from the sandwiches, relative to the threshold odds of 1 in 75,000. When informed of the probabilities, many participants reassessed the opportunity for risk reduction, and were willing to pay more to reduce the threat. While previous research suggests that individuals tend to overestimate low-probability risk, the underestimation may not necessarily conflict with this expectation. Participants appeared to perceive the risk as less likely than the 1 in 75,000 odds presented. Scientifically-

estimated odds actually fall below this threshold value.[19] Subjects' underestimation of the threshold risk levels may be, in fact, an overestimation of the true odds. To draw additional conclusions about participants' naïve beliefs about the probability of illness, more information is required. Analysis of the second treatment reveals a window of perceived risk. Participants tended to believe that the food-borne illness was less likely than 1 in 75,000, but more likely than a 1 in 100,000 chance – an overestimation of the true odds.

Examining only Replications 1, 2, 3 and 6, the null hypothesis of equal means cannot be rejected for the stabilized rounds (Table 5). There is no statistically significant difference between informational stages at a 5 per cent confidence level, as the release of objective disease information had no statistically significant impact on mean bids.[20] These results suggest that participant expectations about the odds and health effects of contracting this food-borne disease were similar to those presented in the auction setting, or that the information had little impact on their perceptions of the risk.

In contrast, results of the WSR test for mean bids from Rounds 11 to 20 and 1 to 10 in Replications 1, 2, 3 and 6 suggest a statistically significant difference between stages (at a 10 per cent level), and conflict with results from the stabilized rounds. Overall, the presence of statistical differences across the stages of this grouping of replications is unclear. Also, as previously mentioned, the informational value of these censored treatments may be limited. Overall, however, there is strong evidence that

[19] The scientifically-estimated probability of *Campylobacter* is approximately 1 in 125,000.

participants' bids increased with the release of objective risk and pathogen information.

Differences in Informational stages - Treatment 2

Similar to the procedure for analysis for Treatment 1, data from Treatment 2 are tested for statistically significant differences in mean bids between informational rounds. Hypotheses identical to those for Treatment 1 were tested at replication and treatment levels. Average bids for the second treatment are presented in Figure 3. Decreases in mean bids after the release of information are visible in Replications 8, 9, 10 and 11. The bottom half of Table 3 summarizes the results of the significance testing undertaken with the data from Treatment 2.

When considering the full set of rounds and examining auctions individually, statistically significant differences between informational stages are found for three of the six of the replications. Inferences drawn from the t-tests and WSR tests are similar for each hypothesis. Statistically significant differences are found for Replications 7, 9 and 11 when all rounds are tested. The positive test statistics for Replication 7 indicate a statistically significant increase in bids across informational stages, while the other replications conform to the expectation of a decrease from naïve to informed stages. In the stabilized rounds (Rounds 7 to 10 and 17 to 20) of Replications 8, 9, 10 and 11, mean bids decreased when information about the pathogen risk was released to participants. Participants may have reduced their willingness-to-pay when they discovered their overestimation of the odds of becoming ill. Although test statistics are positive for

[20] It is important to remember, however, the previous discussion about the experimental value of this censored dataset. There were no remarkable differences in how Replications 4 and 5 were conducted, and neither had an unusual ratio of male to female participants.

Replications 7 and 12, increases are not statistically significant when testing means from the stabilized rounds.

Levene's test for homogeneous variances and the K-W test for equality of distributions reveal mixed results for the second treatment, summarized in the bottom half of Table 4. While the null hypotheses of homogeneous variances and identical distribution functions cannot be rejected for the naïve portion of the auction, there are statistically significant differences in variances and distributions across the informed rounds. The statistically appropriateness of combining the replications in this treatment is unclear. However, the research value gained from considering the combined dataset offsets the doubts caused by the statistic ambiguity, and further tests results are presented for all replications of Treatment 2.

The bottom half of Table 5 presents the results of tests of significant differences across informational stages for all of Treatment 2. Tests of the means of Rounds 7 to 10 and 17 to 20 reveal statistically significant differences between informational rounds, while tests of all rounds fail to reject the hypotheses of equal means. When information about the food safety risk was presented to participants, stabilized mean bids decreased. Participants may have initially overestimated the effects or risk of illness and, when given details about the risk, reduced their bids to reflect the new information. This overestimation corresponds with behavioural research suggesting individuals tend to over-assess the likelihood of low-probability events.

Differences between Treatments 1 and 2

Two treatments are used to measure the difference in marginal risk reduction valuations

and to investigate diminishing marginal value arguments. Treatment 1 involved a reduction in risk from a 1 in 75,000 to 1 in 100,000 chance of becoming ill from *Campylobacter*. Treatment 2 asked participants to value a reduction from 1 in 100,000 to 1 in 125,000 odds of contracting the food-borne disease. While marginal values are theoretically measured for small changes, the nature of the experiment required larger increments to be used – otherwise the marginal changes may have been too small for subjects to appreciate and understand.

T-tests for independent samples and the nonparametric Mann-Whitney (M-W) test of central tendency are used to compare the two treatments and test the null hypothesis that mean bids from Treatment 1 equal mean bids from Treatment 2. Again, this null is tested using bids from all rounds and then bids from only the stabilized rounds. In Table 6, all the replications of each treatment are tested, as well as the group of replications selected in prior analysis. Since all replications were informationally identical in the naïve stage, failure to reject the null hypotheses of equality at a 5 per cent level of significance for Rounds 1 to 10 and Rounds 7 to 10 is as expected. However, parametric test results based on mean bids in the informed rounds differ by treatment, with means in Treatment 1 consistently higher than those in Treatment 2. Failure to reject the null hypothesis using the selected replication groups (*i.e.*, Replications 1, 2, 3 and 6), in contrast to the results from the full treatments, reflects the lost informational value of replications 4 and 5.

The concept of diminishing marginal utility suggests that the first marginal change in risk provides higher utility than subsequent, equivalent reductions. The Jones-Lee framework supports the concept, as the marginal value of a risk reduction increases with

initial risk level, as successive equal reductions in risk are valued less. In fact, positive t-statistics reflect this inequality. Results indicate that participants placed higher value on the first risk reduction (1 in 75,000 to 1 in 100,000 odds) than the second reduction (1 in 100,000 to 1 in 125,000 odds).

Although M-W p-values for the informed rounds are approaching statistical significance, the test fails to identify statistically significant differences between values of marginal risk reductions. Results of the nonparametric testing do not conflict directly with diminishing marginal value arguments, but fail to confirm its presence in the data.

Willingness-to-Pay Estimates

Two scenarios must be examined to establish willingness-to-pay estimates, based on the amount of information given to individuals. The first 10 rounds of all 12 auctions were run identically, representing a situation where a product is marketed as lower-risk without specific pathogen level or symptom information. Presented only with the decision to purchase a lower-risk product versus a typical product, participants were willing to pay a premium of approximately $1.69.[21]

To estimate consumers' willingness to pay for specific food safety risk reductions, mean bids for the informed auction rounds are tested against the null hypotheses of zero means. Based on mean bids from the stabilized, informed rounds of Treatment 1, participants were willing to pay approximately $1.93 for the reduction from 1 in 75,000 to 1 in 100,000 odds in becoming ill from *Camplyobacter* from consuming a chicken

[21] t-stat: 14.8, d.f.: 164, p-value: 0.000

sandwich.[22] Participants were willing to pay approximately $1.38 for the reduction in odds from 1 in 100,000 to 1 in 125,000 chance of becoming ill, according to results from the stabilized, informed rounds of Treatment 2. [23, 24] Since previous valuation experiments have used different pathogens, threshold odds and marginal risk reductions, and participants from different countries, it is difficult to directly compare these results to other studies. However, other research has confirmed that the average consumer is willing to pay for reductions in food-borne pathogens.[25]

Fox *et al.* (1995) and Hayes *et al.* (1995) use a LeChatelier principle argument to contend that these values represent upper bounds on consumers' valuations of improved food safety. The LeChatelier principle asserts that when an economic agent sets all choice variables optimally, the substitution effects are more than short-run substitution effects when some variables are fixed (Deaton and Muellbauer, 1980). That is, demand is less elastic when a subset of variables is fixed. In this case, aspects of the auction are fixed (*e.g.*, it is a one-shot experience and no substitutes were available). Fox *et al.* and Hayes *et al.* state that as constraints are lifted from the auction markets and participants have more choices, bids will decrease. They suggest that introducing substitutes would lead to lower bids for the sandwiches. However, this only holds if the substitutes are lower risk and products' risks are independent. Introducing higher risk products could actually induce higher bids for the sandwiches, as risk-averse individuals pay more to avoid the hazard.

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[22] t-stat: 8.94, d.f.: 80, p-value: 0.000
[23] This estimate differs from the Treatment 2 mean in Table 2 because of the elimination of one outlier.
[24] t-stat: 10.15, d.f.: 83, p-value: 0.000
[25] In a similar auction environment, Hayes *et al.* (1995) reported an average willingness-to-pay of $0.86 for a *Campylobacter* risk reduction. Fox *et al.* (1996) reported average willingness-to-pay values ranging from $0.50 to $1.40 in an examination of consumers' valuations of risk reductions of *Salmonella.*

Substitutes with risk levels not independent of the original auction item's risk could also lead to higher bids, as individuals act to minimize their exposure to the risks.

Results of the treatment comparison confirm the arguments of the Jones-Lee expected utility-based model. Although not every individual submitted non-zero bids for the product upgrade, on average individuals were willing to pay a positive amount to reduce the risk they faced. As hypothesized, the marginal value of a decrease in risk increased with initial risk.

Conclusion

This study aimed to estimate Canadian consumers' willingness-to-pay for food safety risk reductions, while identifying systematic misassessments of food-borne risk. Examination of the bids gathered in the experimental auctions leads to several conclusions about consumers' perceptions and valuations of food safety risk reductions. Without specific risk information, auction participants were willing to pay a $1.69 premium for a lower-risk chicken sandwich. Analysis of auction results suggests that individuals were willing to pay approximately $1.93 for a risk reduction from 1 in 75,000 to 1 in 100,000 probability of illness due to *Campylobacter*, and $1.38 for a reduction from 1 in 100,000 to 1 in 125,000 odds.

Results confirm the hypothesis that individuals are willing to pay for improved food safety, as well as expectations about the diminishing marginal value of risk reductions. Overall, the pattern of over- and under-estimation suggests that participants generally perceived the risk to fall between 1 in 75,000 and 1 in 100,000. This overestimation of the true scientific odds of 1 in 125,000 corresponds with individuals'

tendencies to overestimate low-probability risks, an expectation based on past behavioural research. Moreover, the tendency for bids in Treatment 1 (a higher initial risk of exposure to a food-borne pathogen) to exceed bids in the second treatment (a lower initial risk) is consistent with the Jones-Lee conceptual model and the concept of diminishing marginal value. Willingness-to-pay values for risk reductions increased with higher initial risk levels (once respondents were made aware of the risk levels).

Like many studies based on a small sampling of individuals, the research faces challenges in terms of the generality and applicability of results. Students may not display risk-related behaviour representative of consumers-at-large, facing income constraints that could impact their valuation decisions, and are perhaps generally more willing to assume risk. Individuals who are elderly or have heightened sensitivity to health risks may behave differently, when faced with the same decisions.

The magnitude of the bids themselves seems high. The estimates may need to be scaled to be practically useful in cost-benefit analysis. However, the direction of changes in bids between informational stages, the presence of diminishing marginal values and conclusions about the impact of risk tolerance on relative bidding are consistent with expectations and provide valuable information.

Results of this study provide strong evidence supporting the experimental auction method as a willingness-to-pay measurement tool. Although bid magnitudes must be carefully interpreted, the information gathered reveals interesting and plausible insight into valuation decisions and the assessment of food-related risks.

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Figure 1. Relationship between amount V and probability p, and impact of over- and under-estimation of risks levels and willingness to pay

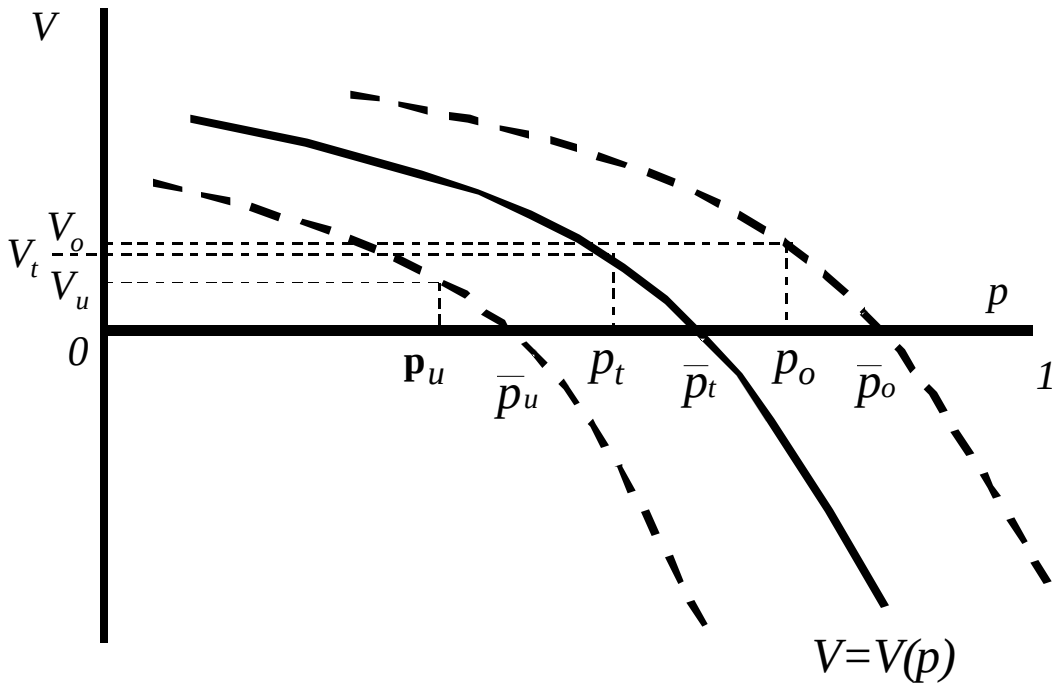

Figure 2. Comparison of mean bids from Replications 1 to 6

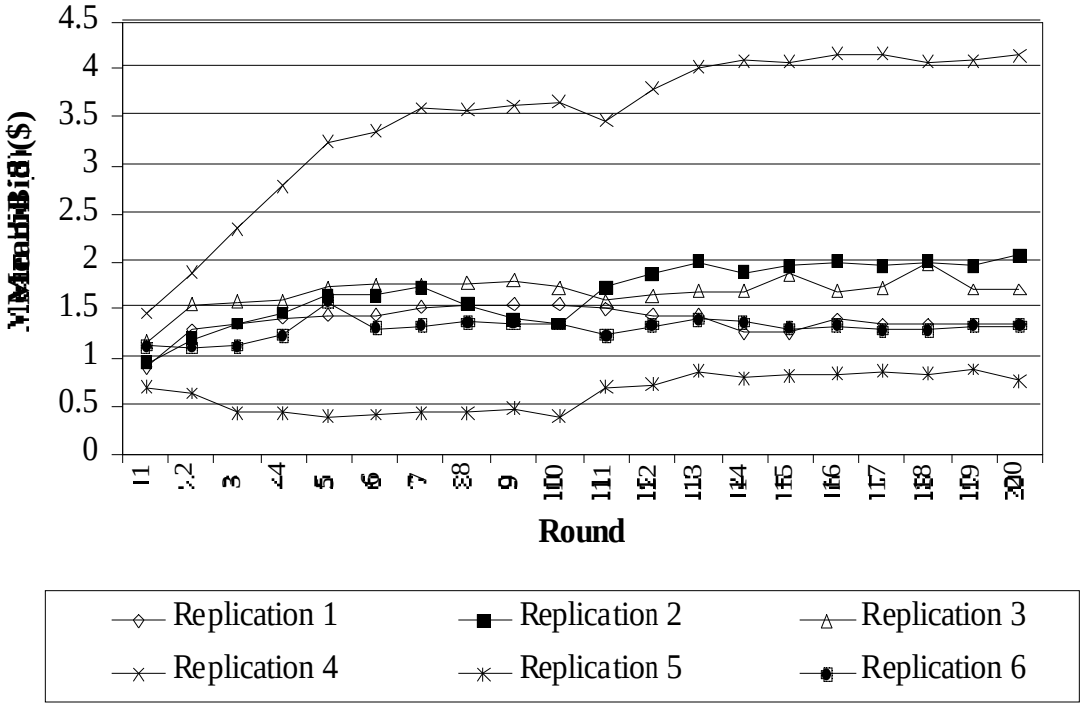

Figure 3. Comparison of mean bids for Replications 7 to 12

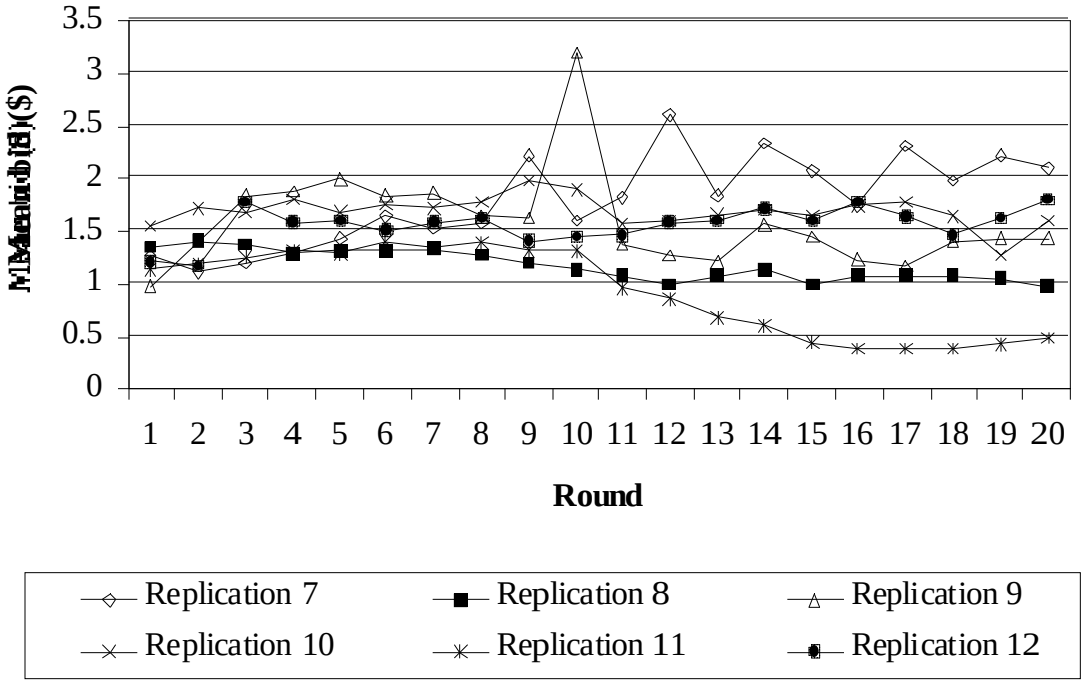

Table 1. Summary of demographic variables.

Variable	Definition	Treatment Averages 1	Treatment Averages 2
Gender	1 if male; 0 if female	0.51	0.47
		(0.50)	(0.50)
Age	Average age category of respondents:	1.21	1.49
	1=18 to 24 years	(0.92)	(1.11)
	2=25 to 29 years		
	3=30 to 34 years		
	4=40 to 44 years		
	5=45 to 49 years		
	6=50 to 54 years		
	7=55 to 59 years		
Adults	Average number of adults in household:	3.48	3.32
		(1.09)	(1.14)
Children	Average number of children in household:	0.63	0.56
		(1.15)	(0.94)
Education	Average education category of respondents:	2.43	2.74
	1=did not complete high school	(0.88)	(1.07)
	2=high school		
	3=college or technical school		
	4=university (degree)		
	5=post graduate (Masters, Ph.D.)		

Note: Numbers in parentheses are standard deviations.

Table 2. Mean Bids for Replications 1 to 12

	Means of Rounds			
	1 to 10	7 to 10	11 to 20	17 to 20
Mean bid in:				
Replication 1	1.40	1.54	1.37	1.35
Replication 2	1.43	1.51	1.94	2.00
Replication 3	1.65	1.77	1.73	1.78
Replication 4	2.95	3.61	4.01	4.11
Replication 5	0.47	0.43	0.80	0.83
Replication 6	1.29	1.35	1.32	1.31
Treatment 1	1.55	1.73	1.90	1.93
Replication 7	2.18	2.81	2.57	2.96
Replication 8	1.30	1.24	1.06	1.05
Replication 9	1.83	2.09	1.36	1.37
Replication 10	1.76	1.85	1.63	1.58
Replication 11	1.30	1.35	0.57	0.43
Replication 12	1.50	1.52	1.64	1.64
Treatment 2	1.66	1.84	1.49	1.53

Table 3. Comparison of naïve and informed mean bids by treatment and replication.[a]

	Difference in mean bids in rounds 11 to 20 and 1 to 10 (i.e., all rounds of bids)		Difference in mean bids in rounds 17 to 20 and 7 to 10 (i.e., stabilized bids)	
	t-test	WSR[b]	t-test	WSR[b]
		Treatment 1		
Replication 1	-0.36	-0.76[c]	-1.71	-1.22[c]
	(0.723)	(0.445)	(0.115)	(0.223)
Replication 2	2.64	-2.44[d]	1.89	-1.61[d]
	(0.019)	(0.015)	(0.080)	(0.108)
Replication 3	0.39	-0.67[d]	0.07	-0.31[d]
	(0.702)	(0.505)	(0.944)	(0.754)
Replication 4	3.01	-2.34[d]	1.59	-1.77[d]
	(0.010)	(0.019)	(0.135)	(0.077)
Replication 5	2.94	-2.40[d]	2.77	-2.43[d]
	(0.013)	(0.017)	(0.018)	(0.015)
Replication 6	0.11	-0.16[d]	0.20	-0.16[c]
	(0.913)	(0.875)	(0.843)	(0.875)
		Treatment 2		
Replication 7	2.61	-1.92[d]	1.40	-0.80[d]
	(0.022)	(0.056)	(0.186)	(0.422)
Replication 8	-1.75	-1.52[c]	-2.18	-2.21[c]
	(0.110)	(0.128)	(0.055)	(0.027)
Replication 9	-2.41	-2.07[c]	-1.80	-1.92[c]
	(0.030)	(0.038)	(0.093)	(0.054)
Replication 10	-0.48	-0.31[c]	-2.27	-1.99[c]
	(0.638)	(0.754)	(0.041)	(0.047)
Replication 11	-2.61	-2.86[c]	-3.16	-2.79[c]
	(0.020)	(0.004)	(0.007)	(0.005)
Replication 12	0.59	-0.91[d]	0.47	-0.66[d]
	(0.562)	(0.363)	(0.648)	(0.507)

a. Values in parentheses are p-values. The closer the p-value to zero, the stronger the argument in favour of rejecting the null hypothesis.
b. Wilcoxen Signed-Rank significance levels are asymptotic.
c. Based on positive ranks.
d. Based on negative ranks

Table 4. Test of equality across replications, by treatment.[a]

	Levene	K-W[b]	Levene	K-W[b]
	Treatment 1			
	Replications 1 to 6		Replications 1,2,3,6	
Rounds 1 to 10	10.75	19.56	3.06	1.33
	(0.000)	(0.002)	(0.036)	(0.722)
Rounds 7 to 10	15.86	21.28	2.86	1.35
	(0.000)	(0.001)	(0.046)	(0.717)
Rounds 11 to 20	20.21	15.47	0.25	3.38
	(0.000)	(0.009)	(0.862)	(0.337)
Rounds 17 to 20	21.56	15.61	0.06	3.82
	(0.000)	(0.008)	(0.980)	(0.282)
	Treatment 2			
	Replications 7 to 12			
Rounds 1 to 10	1.63	3.35	No subsets of Treatment 2 were tested	
	(0.161)	(0.647)		
Rounds 7 to 10	1.63	3.98		
	(0.162)	(0.552)		
Rounds 11 to 20	3.25	13.62		
	(0.010)	(0.018)		
Rounds 17 to 20	3.78	16.51		
	(0.004)	(0.006)		

a. Values in parentheses are p-values. The closer the p-value to zero, the stronger the argument in favour of rejecting the null hypothesis.

b. Wilcoxen Signed-Rank significance levels are asymptotic.

Table 5. Comparison of naïve and informed mean bids across treatments.[a]

	Difference in mean bids in rounds 11 to 20 and 1 to 10 (i.e., all rounds of bids)		Difference in mean bids in rounds 17 to 20 and 7 to 10 (i.e., using stabilized bids)	
	t-test	WSR[b]	t-test	WSR[b]
		Treatment 1		
All replications	3.42	-3.32[c]	2.07	-2.20[c]
	(0.001)	(0.001)	(0.042)	(0.028)
Replications 1,2,3,6	1.57	-1.83[c]	0.72	-0.63[c]
	(0.123)	(0.067)	(0.478)	(0.534)
		Treatment 2		
All replications	-1.35	-1.13[c]	-2.23	-2.49[c]
	(0.180)	(0.258)	(0.028)	(0.013)

a. Values in parentheses are p-values. The closer the p-value to zero, the stronger the argument in favour of rejecting the null hypothesis.
b. Wilcoxen Signed-Rank significance levels are asymptotic.
c. Based on positive ranks.

Table 6. Comparison of mean bids across treatments, by Information Stage.[a]

	Difference in mean bids across treatments, using all replications		Difference in mean bids across treatments using replications 1, 2, 3, 6, and 7 to 12	
	t-test	M-W[b]	t-test	M-W[b]
Rounds 1 to 10	0.06	0.29	-0.56	0.26
	(0.955)	(0.770)	(0.577)	(0.796)
Rounds 7 to 10	0.37	0.22	-0.53	0.28
	(0.712)	(0.828)	(0.598)	(0.777)
Rounds 11 to 20	2.00	1.31	0.93	0.97
	(0.045)	(0.190)	(0.355)	(0.332)
Rounds 17 to 20	2.19	1.42	1.11	1.04
	(0.029)	(0.154)	(0.270)	(0.298)

a. Values in parentheses are p-values.
b. Mann-Whitney significance levels are asymptotic

Appendix - *Product Descriptions*

Product A (Your Sandwich):	**Product B (For Auction):**
This product has a typical chance of contamination by *Campylobacter*, a foodborne pathogen. It was purchased from a local grocery store.	This product has been screened for *Campylobacter*. It has a lower-than-typical chance of being contaminated with a foodborne pathogen.

Treatment 1- Replications 1 to 6:

Product A:	**Product B:**
If you eat this food, there is a **1 in 75,000** chance that you will become ill from *Campylobacter*.	This product has been screened for *Campylobacter*. There is a **1 in 100,000** chance of getting Campylobacteriosis from consuming this food. This represents a 25% reduction in the odds of becoming ill.

Campylobacter may cause diarrhea, abdominal pain, nausea, vomiting, headaches, chills and low-grade fever. Symptoms may last for one to seven days. The actual individual chance of infection of Campylobacteriosis is 1 in 70 annually. Of those individuals who become ill, one individual in 1,000 will die annually.

Treatment 2 - Replications 7 to 12:

Product A:	**Product B:**
If you eat this food, there is a **1 in 100,000** chance that you will become ill from *Campylobacter*.	This product has been screened for *Campylobacter*. There is a **1 in 125,000** chance of getting Campylobacteriosis from consuming this food. This represents a 20% reduction in the odds of becoming ill.

Campylobacter may cause diarrhea, abdominal pain, nausea, vomiting, headaches, chills and low-grade fever. Symptoms may last for one to seven days. The actual individual chance of infection of Campylobacteriosis is 1 in 90 annually. Of those individuals who become ill, one individual in 1,000 will die annually.