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The economics of food safety: an experimental approach

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The economics of food safety:

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DEDICATION

To my parents

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GENERAL INTRODUCTION

Estimates from the Center for Disease Control (CDC) and the Food and Drug Administration (FDA) indicate that between 6.5 million and 33 million Americans are affected annually with food-borne illnesses caused by pathogens in the food supply (Roberts and van Ravenswaay, 1989). These figures comprise between 3 percent and 14 percent of the U.S. population; further, approximately 9,000 of these cases result in death annually (Bennett, Holmberg, Rogers, and Solomon, 1987). In contrast, data provided by the Environmental Protection Agency (EPA) estimates that there are only 6,000 cancer cases, or 2 cases per 100,000 persons, which are caused by foods contaminated by pesticides annually (USEPA, 1987).

The risks to human health from food contaminations can be largely divided into three causes: chemical residues, natural poisons, and pathogenic microorganisms. Chemical residues in food include examples such as alar in red apples; cyanide in Chilean grapes; dioxin in milk; antibiotics and other animal drugs in meat; lead used in the past to solder and seal cans for food storage; pesticides in fruits and vegetables. These and other contaminants have potential effects on food contamination and safety if the food is for human consumption. Natural poisons include products such as aflatoxin in corn and peanuts (CAST, 1989).

Food-borne illnesses can also be caused by pathogenic microorganisms; i.e., by microbial toxins produced in the food before consumption (*Staphylococcal* and *Botulinum* toxins, for example); by infection with bacteria that produce toxins during

their growth in the alimentary canal (*Clostridium perfringens*, *Bacillus cereus*); and by infection from microorganisms or parasites that establish themselves in the alimentary canal or other parts of the body (*Brucella*, *Coxiella*, *Trichinella*, etc.).

In general, pathogenic microorganisms present greater threats to the food supply than do chemical residues or natural poisons. Microbiological agents caused 90 percent of the food-borne illnesses in the United States from 1983 to 1987 (CDC, 1990).

These pathogens, which tend to be widely distributed in the world, are found in the bacterial genera--*Salmonella, Escherichia, Clostridium, Bacillus, Staphylococcus, Streptococcus, Shigella, Vibrio, Brucella, Yershinia,* etc.

Salmonella is a significant problem among the microbes, affecting an estimated one third (35%) of the chicken carcasses after slaughter (Green, 1987; Newsweek, 1989b). Some feel that food handlers and consumers underestimate the effects and level of microbial contamination and resulting food-borne illnesses. The risk of food contamination and associated illnesses from agents such as *Salmonella* can be controlled to a large degree through proper rinsing and preparation. Also, any microbial toxins can be destroyed through proper cooking. However, some microbial toxins such as *Staphylococcal* poison can not be eliminated by heating.

The ideal method of preventing the entry of pathogens into food requires the application of hygienic measures all along the food production chain: processing, storage, distributions and serving. However, for this there are costs as well as benefits. The cost of continuously sanitizing the entire production environment with

a continuous evaluation of conditions can be costly. These costs need to be compared to economic losses resulting from disease.

Food-borne diseases cause large economic losses for society annually. These costs include items such as medical costs, productivity loss, pain and suffering to individuals, food industry losses, and losses within the public health sector (Roberts and van Ravenswaay, 1989). Estimated losses, based largely on an evaluation of direct individual losses, have been presented in congressional testimony to be approximately $1 billion a year for salmonellosis, another $1 billion a year for campylobacteriosis, and $215 million to $323 million for congenital toxoplasmosis (Roberts and van Ravenswaay, 1989). These estimates have included direct costs such as hospitalization costs. However, they likely represent an underestimation of the true economic costs because costs were not computed for willingness-to-pay (WTP) to reduce the probability of illness.

The primary focus of this study is to estimate consumer WTP for enhanced food safety. To accomplish this, a nonhypothetical laboratory experimental approach was developed to measure individual WTP to avoid food-borne illness. The experimental design uses a Vickrey (1961) second-price sealed-bid auction to elicit consumer WTP for enhanced food safety. Five food-borne pathogens are evaluated: *Campylobacter*, *Salmonella*, *Staphylococcus aureus*, *Clostridium perfringens*, and *Trichinella spiralis*.

This research also explores how consumers' naive WTP bids respond when consumers are provided information about the objective probability of contamination and the specific health impacts of alternative food-borne pathogens. The paper

reports and explains the often-observed divergences in WTP and willingness to accept (WTA) measures when measuring nonmarket goods such as food safety. From a public policy perspective, the most important feature of this study involves the estimate of the value to consumers of enhanced safety of the food supply.

Explanation of Dissertation Format

The format of this dissertation follows the Iowa State University alternate dissertation format. This dissertation consists of three papers or sections. Each section represents a manuscript that will be submitted to a professional economic journal. Therefore, the format of each section, especially tables, figures, and references, follows the format of the journal to which it has been or will be submitted. Each section is self-contained with the traditional introduction, discussion areas, summary conclusion, and references. References cited in the general introduction and general summary and discussion sections are included in the literature cited section.

The author conducted the laboratory experiments and performed data and statistical analysis upon which each manuscript is based. Each section was written in consultation with Dr. James Kliebenstein, Dr. Dermot Hayes, and Dr. Jason Shogren.

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SECTION I.

AN EXPERIMENTAL APPROACH TO MEASURING THE VALUE OF SAFER FOOD

INTRODUCTION

There is an optimal level of societal expenditures on food safety. In the absence of any public goods problem this should equal the sum of each individual's optimal expenditures. One measure of the individual's optimal expenditures is his or her willingness to pay (WTP) for safer food. Alternatively, one could estimate how much individuals need to compensate for unsafe food.

The value of having estimates of the measures discussed above is the guidance they would provide to those who must determine how much to spend on the safety of the food supply. Existing food safety expenditures in the United States are determined in part by the government's interpretation of signals sent by consumers via direct contact, interest groups, and the media. Many of those who participate in this process lack information on existing expenditures on food safety as well as the incidence rate or probability of becoming ill from a particular pathogen or chemical contaminant.

Due to the lack of information consumers have underestimated the foodborne risk from the pathogenic microorganisms which are primary cause of foodborne illness and more serious than the chemical or pesticide hazards (Roberts and van Ravenswaay 1989). This estimation process is supplemented by research and testimony on existing hospitalization costs and the opportunity cost of time spent away from work (Roberts 1985, 1989).

Previous estimate of foodborne illness costs have ranged from $4.8 billion (Roberts 1989) to $8.4 billion (Todd 1989), to a high of $23 billion (Gartright et al.

1988) which represents a broad estimate for intestinal infectious diseases. However, it is well known that this cost of illness approach or human capital method (see Linnerooth 1979) underestimates the true cost of the problem because the individuals involved would presumably pay more than the actual costs incurred.

The absence of any information in the United States has created a situation where the general public and the media request continuing improvements in the safety of the food supply. Any further decrease in the incidence rate of pathogens in the United States will come in at an increasing cost, an interesting question therefore is at what point the cost will exceed the benefits. To answer this questions, van Ravenswaay (1988) reviewed the limited literature about the consumers demand of food safety. This survey paper summarized what is known about consumers' concerns and who has the responsibility about food safety and suggested the methodological approaches to obtain this information. Van Ravenswaay emphasized the key question in food safety research has been individuals' WTP for risk or exposure reductions, and concluded with " We know nothing about the demand for food safety and...." that the more research were needed to find the knowledge of consumers' concerns and the methods of evaluating the WTP values about food safety.

To the author's knowledge, no scientific method has yet been implemented to measure sickness costs. This is despite the need for this estimate from those involved in lawsuits where illness has occurred as well as those who are responsible for expenditures on food safety. The absence of any estimates illness (or morbidity) costs in the literature is understandable. Individuals themselves may have difficulty putting

a monetary value on sickness and it is not surprising that others would feel uncomfortable aggregating across such uncertain estimates.

One way to measure these costs and benefits would be to survey consumers directly. Mitchell and Carson (1989) provide a good overview of the this contingent valuation methods used to estimate values when the item in question does not have a price. Regardless of how well these surveys are designed, however, respondents know that they are responding to a hypothetical situation. Penner et al. (1985) conducted food safety survey which have broad questions about consumers willingness to pay for safety label in meat product. Seventy-one percent of the respondents would pay slightly more or considerably more for the safety information. Slightly more than one-fourth (28 percent) were willing to pay more than 3 cents per pounds of meat products. Consequently, the results are too general to use as a indicator of consumers food safety concern.

Recently, an alternative to the survey based methodology has been developed. This experimental approach attempts to force participants to concentrate better on the question by simulating real world decisions in a laboratory environment (Smith 1982). Previous studies to estimate willingness to pay for reducing the foodborne risk directly applied to the laboratory experiment approach were not found in the literature. However, laboratory experiments are often used to test the principles of economic theory (Kahneman et al. 1990) or to induce the valuation in environmental economics and public good provision (Brookshire and Coursey 1987). The valuation

experiment of nonmarket good such as visibility (Rowe et al. 1980) were implemented in the hypothetical settings.

One exception was the work by Coursey, Hovis and Schulze (1987), who conducted a survey and series of experiment in nonhypothetical setting to examine the disparity of the WTP measure to avoid and willingness to accept (WTA) measure to endure an unpleasant taste experience. WTP value were asked to subjects with description of the bitter taste, but harmless chemical on SOA (sucrose octa-acetate) in survey, not tasting of SOA. Also, they conducted the experiment to elicit the individual bids in a Vickrey (1961) auction setting. The fifth-price sealed-bid auction with iteration was used as a demand revealing mechanism. They concluded that there was not a significant disparity between two values from the experiments. Subjects of experiment had a chance to taste the SOA before their bidding for WTP and WTA, they were bidding the values with the certain consequence of auction outcomes. This study was nonhypothetical in the sense that those whose bids were not accepted were required to swallow a small amount of SOA to receive the compensation that was agreed upon.

Before this experiment, Knetsch and Sinden (1984) also examined the disparity of two values with choice of uncertain outcome of lottery tickets. This experiment used the one shot experiment instead of Vickrey auction mechanism. Most of their results suggested that the selling lottery was less traded than the buying lottery, i.e., willingness to accept measures were greater than the willingness to pay measures. However, Coursey et al. criticized the Knetsch and Sinden's experiment results.

Their disparity of the two values was attributed to the uncertainty in experiment design where this uncertainty could cause the preference reversal phenomenon in monetary bidding procedure and to the use of one shot experiment instead of Vickrey auction--an efficient demand-revealing mechanism. The food safety experiment are based on these nonhypothetical setting with certainty of the choice to reduce the foodborne risk in Vickrey auction setting.

In this paper we use this experimental approach to measure how much individuals would be wiling to pay to remove existing levels of food-borne pathogens from a particular meal. In designing the experiments described below, we took great pains to convince participants that one sandwich had a greater probability of being contaminated than a more expensive alternative. The hope was that by using real risks and real money the participants would be forced to concentrate on the trade-off between risks and returns and in so doing provide a more accurate value. Such isolation of food-borne risk and human behavior in food safety experiment by controlling the noise from the environment infers the value of WTP precisely (Hoffman and Spitzer 1985).

Another advantage of using nonhypothetical food safety experiment is that the lab experiment can be used as a source of data. The lack of information in food safety area is not easily able to perform the theory-intensive approach such as demand-based method and hedonic price method. However, the observation-based experimentation provides the data such as true economic costs of food safety and are

relatively inexpensive method compared to the collection of new data from the market (Hoffman and Spitzer 1985).

One additional benefit of this experimental approach is that we could directly measure the monetary value of increasing the safety of the U.S. food supply without first estimating risk aversion and the monetary value of a bout with illness. In the methodology used, participants perform their own multiplication of probability and pay-off.

The experimental methodology used here has some drawbacks. In particular, it is unclear how far one can generalize the results. Also, it is unclear how group composition and group dynamics influence the experimental results. A secondary purpose of this paper is to examine the sensitivity of the experimental results to changes in the reported probabilities and changes in the composition of the groups themselves. The literature on nonhypothetical experiments is still in its infancy. The results presented in this paper contribute by providing heretofore unreported measures of errors induced by group dynamics and the extent to which participants in nonhypothetical group auctions behave in a rational manner.

The first section of the paper describes ten experiments each with approximately 15 participants that were performed to measure WTP and WTA for the five most common food-borne pathogens in the United States. The second section describes a follow-up experiment where we changed (a) only the people in each group (trials 1 through 10), and (b) the reported risks associated with the less safe food (trials 11 through 20), and (c) the name of foodborne pathogens to a

generic foodborne pathogens (one experiment). The last section draws from the experimental analysis and those results which are useful for policy analysts and for others who may wish to run nonhypothetical experiments.

EXPERIMENTAL DESIGN AND PROCEDURE

In each of the ten experiments described in this section, approximately 15 individuals were paid to participate in a Vickrey second-price sealed-bid auction. The first five experiments attempted to estimate individual WTP for a safe food, and the second attempted to measure how much one had to pay individuals to eat (WTA) a potentially unsafe food. Appendix 1 contains a sample instruction brochure. We began by announcing to several nonintersecting classes of undergraduate students that an experiment providing an approximate stipend of $18.00 and a "free lunch" was scheduled and that volunteers were requested to sign up. Fifteen participants and two alternatives were chosen from each class and asked to appear at an on-campus taste-testing room. This taste-testing room is regularly used to measure reactions to experimental products developed at a nearby facility.

The benefits of using Vickrey's second-price sealed-bid auction (Vickrey 1961) are that each participant submits a bid equal to his/her actual value, independent of the other bidders' behaviors, and that truth is the dominant strategy (Cox et al. 1982). Furthermore, the auction iteration process allows the learning effects to participants and the revelation of their true preference (value) to auctioned items (Coursey 1987).

In each experiment, fifteen participants were first familiarized with the experimental procedure with a candy bar auction. Participants were given a small candy bar and told to bid for a larger candy bar. It was made clear that the student whose bid was successful would pay the monetary bid and get the larger candy bar.

We explained that we wished to measure how much they were willing to pay to upgrade their candy bar.

The candy bar experiment had five trials. In each trial, participants with $3 initial income wrote down their bids and these bids were collected by one of three monitors who then made public the first-highest bidder and second-highest bids. At the end of the fifth bidding trial, one of the trials was randomly selected to be binding. In this binding trial, the second-highest bid was used. The individual responsible for this bid paid the bid amount and upgraded his or her candy bar.

Next, participants were shown two meat sandwiches. We explained that one had been stringently screened for pathogens. The second experimental product was described as having a typical chance of contamination with one of the five most common food-borne pathogens in the United States: *Campylobacter*, *Salmonella*, *Staphylococcus aureus*, *Trichinella spiralis*, and *Clostridium perfringens*. The descriptions used in each case are presented in Appendix 2.

Participants were asked to bid to upgrade to the safer sandwich. It was made clear that, with the exception of the individual whose bid was ultimately selected, all other bidders would be required to eat one of the experimental sandwiches or forfeit the $15 provided. After ten trials of bidding, participants were provided information on the odds of being contaminated from consuming the experimental food and a description of the food-borne illness. The probabilities provided were those for a typical U.S. consumer becoming ill from that particular pathogen for one meat-based meal and were therefore quite accurate. These odds are presented in Table 1. A

further ten bid trials followed the introduction of this information. After all 20 trials had been completed, one binding trial was randomly selected, as before.

The five WTA experiments were identical except that 14 stringently-screened sandwiches and one test product were used. In this case we measured how much we had to pay someone to eat the test product. The differences in the instruction brochures are indicated with [ ] in Appendix 1.

EXPERIMENTAL RESULTS

Willingness to Accept

Figure 1 shows the average WTA results by trial and by pathogen. These data are summarized and compared to the equivalent WTP values in Table 2. The average WTA values of all five pathogen experiments significantly exceed the average of WTP values in all inexperienced one-shot bids (trial 1), naive bids (trials 7 through 10), and informed bids (trials 17 through 20). The *Salmonella* experiment is the extreme case. The average WTA value of the inexperienced one-shot bid is more than thirteen thousand times greater than the average WTP value. Even with repeated exposure to the auction market in naive bids and with detailed information of the food-borne illness in informed bids, the divergence between WTP and WTA values remained significant. We include these WTA values for comparison; however, it is likely that these values are overestimates for the following reasons.

1. From Prospect theory, we know that the shape of value function is generally concave for gains (safer food) and convex for losses (less safe food) and that from any reference point the slope for losses is steeper than that for the gains (Kahneman and Tversky 1979). Subjects asked an extremely high WTA value (compensation) to give up the screened food they had already acquired because health risk is not easily substitutable for money (see Hanemann 1991 and Shogren et al. 1991).

2. The WTP measure is more appropriate and accurate than the WTA measure for public goods in valuation settings because the degree of loss aversion is sensitive

to the existence of nonmarket or market-like environments (Brookshire and Coursey 1987).

3. For our purposes, these WTA values can be regarded as the cost to society of reintroducing pathogens into a previously safe world, whereas the WTP values are the benefits of eliminating pathogens from the existing U.S. food supply.

4. In these WTA experiments, all but one of the participants ate the stringently-screened food, whereas in the WTP experiments, only one participant ate the "safer" food. One would imagine that, as the more risk-averse individuals bid against each other for the one safe sandwich, the WTP bids would be higher than the WTA bids; yet the opposite was the case. In all cases, the WTA bids were significantly higher (see Table 3). This phenomenon has been observed by others (Knetsch and Sinden 1982; Coursey et al. 1987).

5. For policy purposes, the WTP bids are more useful because the WTA bids were probably inflated because participants asked for large monetary values in hopes of making more than the promised $15.00, whereas in the WTP case participants had to provide the cost and were more careful with their bids. Also, the WTP bids measured the benefits of reducing pathogens from today's levels, whereas the WTA measure implicitly assumes a world where food-borne pathogens have all but been eliminated and then measures the welfare loss of reintroducing pathogens. The WTP and WTA results are very different. For these reasons, we will focus on the WTP results.

Willingness to Pay

Figure 2 shows the average bid for trials 1 through 20 for each of the pathogens for each of the WTP experiments. The averages for the first bid are similar to those one would receive from a survey that was answered truthfully and without information. Bids in trials 2 through 10 allow for the gaming and informational flow of the auction process. Information on the probability and nature of food-borne illness was introduced in trial 11, and increased the average bid for all pathogen cases of WTP. In trials 1 through 10, individuals were told that the test product had a typical chance of being contaminated, whereas in trials 11 through 20, individuals knew the actual probability.

The average WTP for *Staphylococcus aureus* in trials 1 through 10 was greater than that for the other pathogens, possibly because of a lack of familiarity with this name. When information about the true probability and nature of the food-borne illness was introduced, average bids increased in all cases. The increase was particularly large for *Campylobacter*. The results for trials 17 through 20 are most useful for policy. The bids reflect information obtained after the bidding process had settled down. These figures tell us that the typical participant would be willing to pay between 42¢ and 86¢ per meal to reduce the probability of food-borne illness caused by the presence of each pathogen to the true odds of 1 in 100 million.

Table 3 compares the mean of trials 7 through 10 with the mean of trials 17 through 20. The t-test and signed-rank test indicate that the WTP differences between naive and experienced bids for *Salmonella* and *Clostridium perfringens* were

statistically significant at the 1 percent significance level. The mean differences in *Campylobacter* and *Staphylococcus aureus* were statistically significant at the 5 percent significance level, and *Trichinella spiralis* was significant at 10 percent significance level. It indicates that subjects' bids of the each experiment were responded to the information provided at trial 11.

Table 3 also compares the prior subjective probability of contamination from the subjects' questionnaires with the true probability provided in trial 11. Interestingly, the provision of the true probability increased WTP when this probability was greater than the subjective probability in *Campylobacter*, *Salmonella*, and *Trichinella spiralis* experiments and decreased WTP when the opposite was the case in *Clostridium perfringens*. Figure 4 has the results of closer analysis of the value of information and the subjects' behaviors exposed to the repeated auction market. AT trial 11, subjects bids were jumped by large amount from trial 10. Even *Staphylococcus aureus* and *Clostridium perfringens* experiment bids were increased. Compared to the trial 20, their bids were decreased by 14¢ and 20¢ lower than the trial 10. Only *Salmonella* and *Campylobacter* experiments are statistically significant in difference between trial 10 and 11, in which the experiments with subjective probability were lower than the actual. At trial 20, after experiencing the repeated market exposure, bids were lower than the trial 10 and in *Clostridium perfringens* 20¢ lower than the trial 10. The value of information were realized quite high in every trial 11. However, subjects responded to the repeated auction market with lower bids

based on their subjective probabilities. Overall, full information and repeated exposure to the auction market had an impact on average WTP values.

If one believed that the results for trials 17 through 20 accurately reflect the participants' WTP to eliminate each of the pathogens, then consumer WTP to eliminate all five pathogens would be the sum of the individual bids for each pathogen. It is not immediately clear, however, that participants were responding in such a logical manner. For example, for *Clostridium perfringens* the true odds (i.e., those reported for trial 11) were 1 in 26 million[1] and yet participants were willing to pay about 42¢. This WTP value is lower than those for the other pathogens, but not by an amount commensurate with the odds. This may be true because some participants ignored the information provided and/or because the presence of any risk, no matter how small, decreased the utility of the product.

For trials 7 through 10, the maximum of the mean bids was 92¢ (for *Staphylococcus aureus*), whereas the minimum was 44¢ (for *Salmonella*). For trials 17 through 20, the maximum was 86¢ (for *Camplyobacter*) and the minimum was 42¢ (for *Clostridium perfringens*). This range in mean values is much less than one would have expected, given the differences in the nature of the pathogens and the large differences in the probability of infection. This lack of response to specific measures of risk is somewhat troubling and may indicate that participants were responding to the presence of risk rather than to the level of risk. To test this hypothesis, we need additional information on how the mean results would change if nothing (other than

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[1]The odds reported for the stringently-screened product were 1 in 100 million.

the participants) was changed (this would allow us to estimate the within-group variability) and if the odds of infection were arbitrarily changed (this would allow us to determine the extent to which the participants responded to the probabilities we provided) and if the specific pathogens name and description was changed to generic foodborne illness (this would verify the response to presence of risk rather than the risk level). To address these issues, an additional six experiments were conducted. These results are discussed in the next section.

THE GENERALITY OF THE EXPERIMENTAL RESULTS

To derive more meaningful policy implications from these experiments, one must assume that people responded in a rational way to the probabilities that were provided. The experiments just discussed accurately portrayed the probabilities and WTP for a single meal. Can we assume that these values double if two meals are involved? Equivalently, can we assume that the value doubles if the probability of infection is doubled?

To answer these questions, we re-ran the *Salmonella* WTP experiment five times. The only difference among these *Salmonella* experiments was the probability provided after trial 10. In the first of these experiments, we reported the odds of becoming sick as one in 13.7. In each of the five subsequent experiments, we increased these odds by a factor of 10. These results are summarized in Figure 3 and Table 5. Notice the relatively wide range in WTP before trial 11. All six of these experiments were identical in every way before trial 11. Any differences that exist prior to trial 11 can therefore be attributed to differences among the six groups in terms of their composition and the group dynamics they exhibited. The range of the mean values at trials 7 through 10 was from 44¢ to $1.32. This range is greater than that obtained when alternative pathogens were used (see Table 3).

In one experiment, shown by (▪) in Figure 3, the second reported bid was lower than the first. This convinced most participants that they had overbid and became a self-fulfilling expectation. In the experiment denoted by (▲) in Figure 3, the opposite occurred.

As expected, WTP increased dramatically when participants discovered that there was a 1 in 13.7 chance that the sandwich was contaminated. Also expected was the dramatic decrease when the 1 in 1.37 million odds were used.[2] However, WTP did not increase in proportion to the changes in the odds but rather in proportion to the common log of the odds. The regression results were

$$\underset{}{WTP} = \underset{(0.365)}{1.920} + \underset{(0.091)}{0.2910} * LOG_{10}(Probability). \quad R^2 = 0.72$$

This regression is demonstrated in Figure 4, where we fit a semi-log regression through the WTP results. For each tenfold change in probability, WTP increased by 29¢. These results seem to indicate that participants do not increase their WTP to fully reflect the changes in the odds. For example, had we doubled the odds in the original *Salmonella* experiment, WTP would have increased from 55¢ to approximately 60¢ and not to $1.10 as one would expect.

These additional *Salmonella* experiments shed some light on the original experiments. Participants bid a relatively high value to avoid the *Clostridium perfringens*-tainted sandwich, not because they were particularly concerned about the pathogen but because they failed to incorporate some of the information we provided on incidence rates. The additional results also show that any attempt to rank the pathogens by using the WTA or WTP trials would be meaningless. The intra-group variability (as measured by the range of the *Salmonella* results) is greater than the

[2]In this case, the reported odds for the test product were greater than those for the stringently-screened product, a feature that was not fully reflected in the bids until trial 17.

variability of responses among pathogens. Any differences we detected among the pathogens in the first ten trials can therefore be attributed to the different participant groups we used. These results also indicate that participants overestimated the very small odds, underestimated the very large odds, and reacted to the presence of risk as much as to the actual level.

One additional experiment with generic foodborne pathogen name supports that the ranking of the important foodborne pathogens to consumers' welfare would be meaningless, because consumers reacted to the presence of the foodborne illness risk rather than to the level of the foodborne risk level. Table 6 conclude that the subjects bid with the same pattern as the specific pathogens experiments. The average bid of trials 7 through 10 was 73¢ and 78¢ for the trials 17 through 20, in which was within the same range from 44¢ to $1.32.

Participants were forced to choose between two meals: one which they knew was safe and one that had a small probability of being infected with an unsafe pathogen. The participants consistently chose to pay between 40¢ and $1 to purchase the safer product. Despite our efforts to glean pathogen-specific information from this experiment, about all that one can conclude is that participants were willing to pay approximately 70¢ to upgrade to the safe food. This figure is the simple average of the means of trials 17 through 20 from the five original WTP experiments. The WTP bid of 78¢ in generic foodborne experiment was higher than the average WTP of five WTP experiments because the actual odd was added up the odds of the five pathogens (see Appendix 2).

CONCLUSIONS AND IMPLICATIONS FOR POLICY

To date, measures of the benefits to society of further improvements in the safety of the food supply or of the costs of existing levels of food-borne illness have ignored the pain and suffering involved in being ill. In so doing, the literature underestimates the true figures. In this paper we develop and implement an experimental procedure that causes the participants to evaluate and report their WTP to purchase a meal with a much lower probability of contamination than existing levels.

The results show that this experimental method is a blunt instrument. The experiment forced participants to evaluate their WTA and WTP and to report these values in an honest manner. However, because the participant did not incorporate all the pathogen-specific information, one cannot interpret these results on a pathogen-by-pathogen basis.

If we take the *average* WTP from trials 17 through 20 as a measure of the benefit per meal of safer food (70¢) and multiply this by the number of meals per year that might possibly be contaminated[3], we obtain an average WTP of $364 per participant per year. If we are prepared to make equally heroic assumptions, we can extend the *Salmonella* experiments to indicate that participants would pay

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[3]Not all meals are unsafe. Some meals are prepared at home in a fool-proof fashion; others are not complex enough to contain pathogens (e.g., coffee). In the pretrial survey, we asked participants how many meat-based meals they ate per week. The average response was 7.5; therefore, we assume that only 10 meals per week might possibly be contaminated.

approximately 29¢ per meal or $150 per year to reduce existing levels of food-borne pathogens by a factor of 10. If the participants in this study reflect the average U.S. consumer, the aggregate WTP for the United States is $91 billion for almost complete elimination and $38 billion for a tenfold reduction.

These figures are considerably greater than previous estimates and yet are based on a conservative interpretation of our experimental results. We have not attempted to measure how much it would cost to reduce or eliminate these pathogens; however, it seems likely that a great deal could be done for less than $38 billion to $91 billion. Perhaps this explains the current emphasis on food safety in the United States and other developed countries.

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TABLES AND FIGURES

Table 1. Probabilities of the five foodborne illnesses

Disease Agent	Percent of Foodborne	Foodborne Cases Per Year	Fatalities		Probability Per Meal
			%	#	
Campylobacter	100	2,100,000	0.1	2,100	1/125,143
Salmonella	96	1,920,000	0.1	1,920	1/137,000
Staphylococcus aureus	17	1,513,000	0.08	1,210	1/173,694
Trichinella spiralis	100	100,000	1.0	1,000	1/2,628,000
Clostridium perfringens	100	10,000	1.0	100	1/26,280,000

Note: Data calculated from the Bennett et al. (1987).
Note: Approximate population is 250 million.

Table 2. Comparison of WTP and WTA of five pathogens

Pathogen (Probability of Illness)	Inexperienced One Shot (1st Trial)	Naive (7th-10th Trials)	Informed (17th-20th Trials)
	Mean	Mean	Mean
Campylobacter (1/125,143)	WTP = 0.60 (0.50) WTA = 5.06 (4.55)	WTP = 0.71 (0.43) WTA = 2.36 (3.89)	WTP = 0.86 (0.38) WTA = 3.03 (4.39)
Salmonella (1/137,000)	WTP = 0.61 (0.53) WTA = 8029 (25957)	WTP = 0.44 (0.23) WTA = 8.01 (25.46)	WTP = 0.55 (0.25) WTA = 1.62 (2.00)
Stapylococcus aureus (1/173,694)	WTP = 0.97 (0.39) WTA = 5.55 (7.86)	WTP = 0.92 (0.32) WTA = 3.89 (8.19)	WTP = 0.84 (0.33) WTA = 56.2 (205.87)
Trichinella spiralis (1/2,628,000)	WTP = 0.48 (0.42) WTA = 12.8 (24.80)	WTP = 0.69 (0.46) WTA = 10.51 (25.36)	WTP = 0.81 (0.55) WTA = 18.0 (50.82)
Clostridium perfringens (1/26,280,000)	WTP = 0.64 (0.63) WTA = 30.2 (50.56)	WTP = 0.58 (0.41) WTA = 1.98 (1.37)	WTP = 0.42 (0.33) WTA = 2.21 (1.70)

Note: Sample sizes are as follows: *Camplyobacter* (WTP = 15, WTA = 14), *Salmonella* (WTP = 15, WTA = 15), *Stapylococcus aureus* (WTP = 12, WTA = 15), *Trichinella spiralis* (WTP = 13, WTA =15), *Clostridium perfringens* (WTP = 13, WTA = 15).

Note: Sample standard deviations are in parentheses.

Table 3. Comparison of WTP of five pathogens experiments

Experiment	Probability of Illness			$H_0 : WTP_{17\text{-}20th} = WTP_{7\text{-}10th}$ $H_1 : WTP_{17\text{-}20th} \neq WTP_{7\text{-}10th}$		
	Actual	Subjective	Mean[a]	Mean[c]	t-test[d]	Sign rank test[e]
Campylobacter	1/125,143	1/994,550	$WTP_{17\text{-}20} = 0.86$ (0.38)[b] $WTP_{7\text{-}10} = 0.71$ (0.43)	$WTP_{Diff} = 0.15$ (0.30)[b]	2.33*	24*
Salmonella	1/137,000	1/212,000	$WTP_{17\text{-}20} = 0.55$ (0.25) $WTP_{7\text{-}10} = 0.44$ (0.23)	$WTP_{Diff} = 0.11$ (0.10)	4.13**	39**
Staphylococcus aureus	1/173,694	1/2,927,807	$WTP_{17\text{-}20} = 0.84$ (0.33) $WTP_{7\text{-}10} = 0.92$ (0.32)	$WTP_{Diff} = -0.08$ (0.12)	-2.14*	-21*
Trichinella spiralis	1/2,628,000	1/6,186,440	$WTP_{17\text{-}20} = 0.81$ (0.55) $WTP_{7\text{-}10} = 0.69$ (0.46)	$WTP_{Diff} = 0.12$ (0.25)	1.59	19
Clostridium perfringens	1/26,280,000	1/313,843	$WTP_{17\text{-}20} = 0.42$ (0.33) $WTP_{7\text{-}10} = 0.58$ (0.41)	$WTP_{Diff} = -0.16$ (0.27)	-2.25*	-26**

Note: Sample size are as follows: *Camplyobacter* (WTP = 15), *Salmonella* (WTP = 15), *Stapylococcus aureus* (WTP = 12), *Trichinella spiralis* (WTP = 13), Clostridium perfringens (WTP = 13).

[a] Mean of trials 17 through 20 and mean of trials 7 through 10.

[b] Sample standard deviation are in parentheses.

[c] Difference between the mean of trials 17 through 20 and mean of trials 7 through 10.

[d] *, ** denotes rejection of H_0 at the 0.05, 0.01 significance level for two-tail t test.

[e] *, ** denotes rejection of H_0 at the 0.05, 0.01 significance level for Wilcoxon signed-rank test.

Table 4. Comparison between trials within WTP experiment

Pathogens (Probability of illness)	WTP between 11^{th} and 10^{th} H_0: $WTA_{11} = WTA_{10}$ H_1: $WTA_{11} \neq WTA_{10}$			WTP between 20^{th} and 10^{th} H_0: $WTA_{20} = WTA_{10}$ H_1: $WTA_{20} \neq WTA_{10}$		
	Mean of difference	t-test	Sign-rank test	Mean of difference	t-test	Sign-rank test
Campylobacter (1/125,143)	0.38 (0.42)	3.47**	39**	0.17 (0.21)	3.15**	28**
Salmonella (1/137,000)	0.17 (0.25)	2.64*	27**	0.11 (0.14)	3.09**	21.5**
Staphylococcus (1/173,694)	0.05 (0.18)	0.88	11.5	-0.14 (0.10)	-4.75**	-31**
Trichinella (1/2,628,000)	0.06 (0.28)	0.79	18.5	0.07 (0.25)	0.99	8.5
Clostridium (1/26,280,000)	0.14 (0.68)	0.71	6.5	-0.20 (0.31)	-2.37*	-20.5*

Note: *,** denotes rejection of H_0 at the 0.05 and 0.01 significance level for t-test and sign-rank test.

Table 5. Summary statistics of tests within each *Salmonella* experiment

$H_0 : WTP_{17\text{-}20th} = WTP_{7\text{-}10th}$ $H_1 : WTP_{17\text{-}20th} \neq WTP_{7\text{-}10th}$				
Experiment (Probability of ilness)	Difference (Mean of trials 17th-20th - 7th-10th)			
	Mean[a]	Mean[c]	t-test[d]	Sign rank test[e]
1/13.7	$WTP_{17\text{-}20} = 1.42$ (0.57)[b] $WTP_{7\text{-}10} = 0.54$ (0.30)	$WTP_{Diff} = 0.88$ (0.36)[b]	9.04**	52.5**
1/137	$WTP_{17\text{-}20} = 1.76$ (0.80) $WTP_{7\text{-}10} = 0.88$ (0.45)	$WTP_{Diff} = 0.88$ (0.57)	5.84**	45.5**
1/1,370	$WTP_{17\text{-}20} = 0.50$ (0.21) $WTP_{7\text{-}10} = 0.52$ (0.20)	$WTP_{Diff} = -0.02$ (0.09)	-0.84	-11.5
1/13,700	$WTP_{17\text{-}20} = 0.92$ (0.30) $WTP_{7\text{-}10} = 0.67$ (0.23)	$WTP_{Diff} = 0.25$ (0.12)	8.15**	52.5**
1/137,000	$WTP_{17\text{-}20} = 0.55$ (0.25) $WTP_{7\text{-}10} = 0.44$ (0.23)	$WTP_{Diff} = 0.11$ (0.10)	4.13**	39.0**
1/1,370,000	$WTP_{17\text{-}20} = 0.02$ (0.06) $WTP_{7\text{-}10} = 1.32$ (0.95)	$WTP_{Diff} = -1.30$ (0.93)	-5.42**	-45.5**

Note: The sample size are as follows: 1/13.7 (n = 14), 1/137 (n = 14), 1/1,370 (n = 15), 1/13,700 (n = 15), 1/137,000 (n = 15), 1/1,370,000 (n = 15).

[a]Mean of trials 17 through 20 and mean of trials 7 through 10.

[b]Sample standard deviation are in parentheses.

[c]Difference between the mean of trials 17 through 20 and mean of trials 7 through 10.

[d]The t statistics are shown and ** denotes rejection of H_0 at the 0.01 significance level for two-tail t-test.

[e]The critical values are shown and ** denotes rejection of H_0 at the 0.01 significance level for Wilcoxon signed-rank test.

Table 6. Summary of generic foodborne illness experiment

Probability		Inexperienced	Naive		Informed		
Actual 1/46,585	Subjective. 1/733,423	(1st trial)	7 - 10th	10th	11th	17 - 20th	20th
Mean WTP		1.32 (2.00)	0.73 (0.46)	0.63 (0.44)	1.03 (0.98)	0.78 (0.41)	0.81 (0.45)

WTP between 11th and 10th $H_0 : WTP_{11} = WTP_{10}$ $H_1 : WTP_{11} \neq WTP_{10}$			WTP between 20_{th} and 10_{th} $H_0 : WTP_{20} = WTP_{10}$ $H_1 : WTP_{20} \neq WTP_{10}$		
Mean of difference	t-test	Sign-rank test	Mean of difference	t-test	Sign-rank test
0.40 (0.79)	1.96*	32.5**	0.18 (0.26)	2.67**	38***

*,**,*** denotes rejection of H_0 at the 0.10, 0.05, and 0.01 significance level for t-test and sign-rank test.

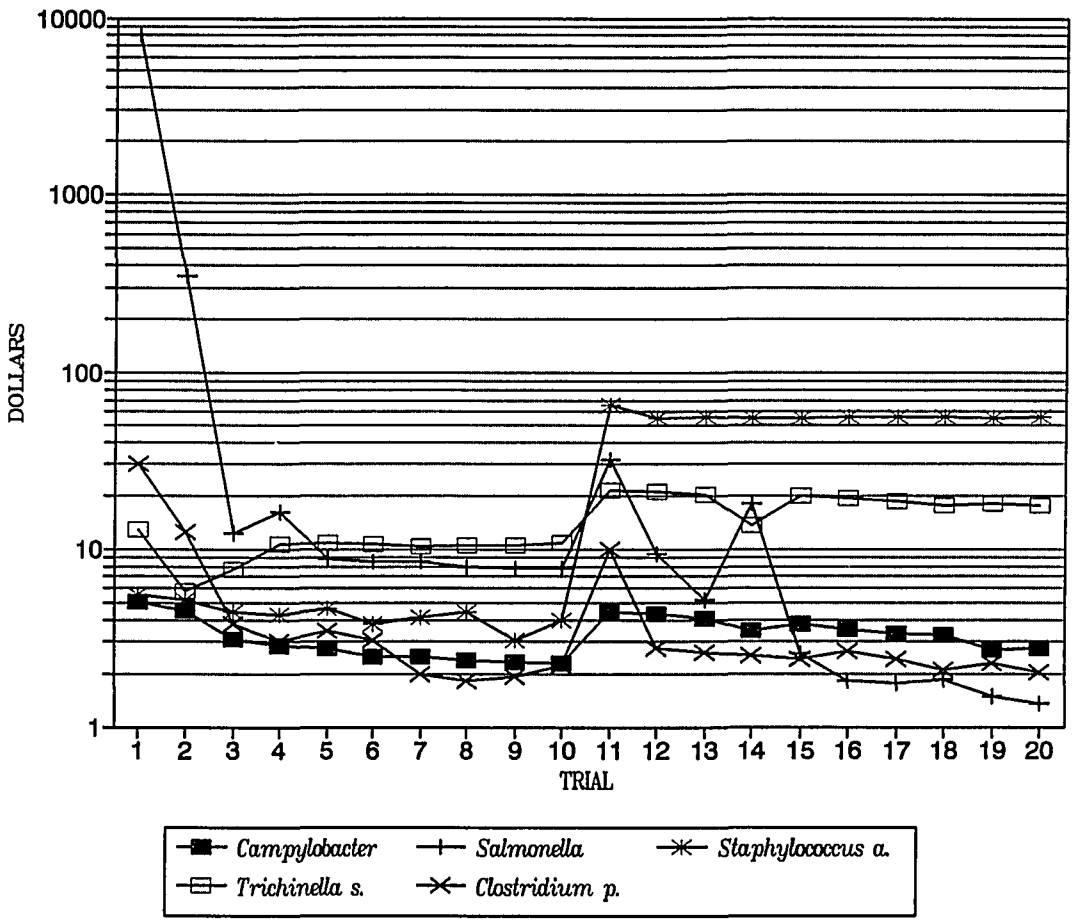

Figure 1. Comparison of average WTA: Five foodborne pathogens

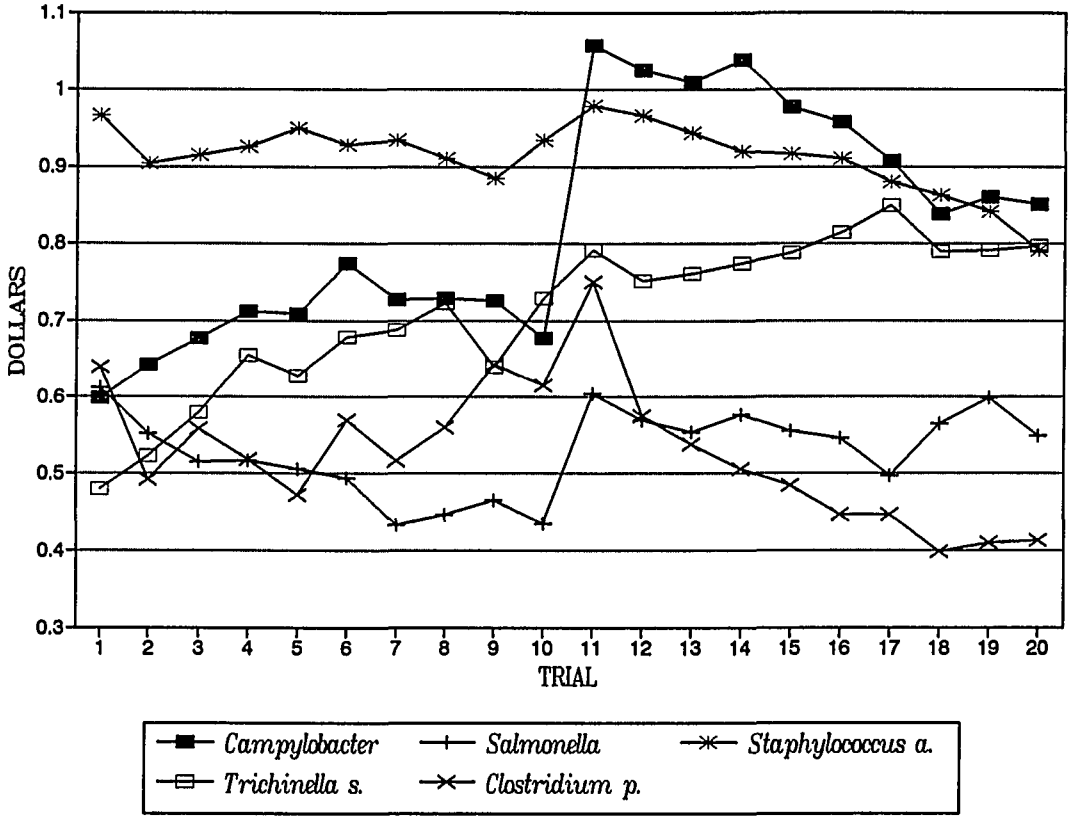

Figure 2. Comparison of average WTP: Five foodborne pathogens

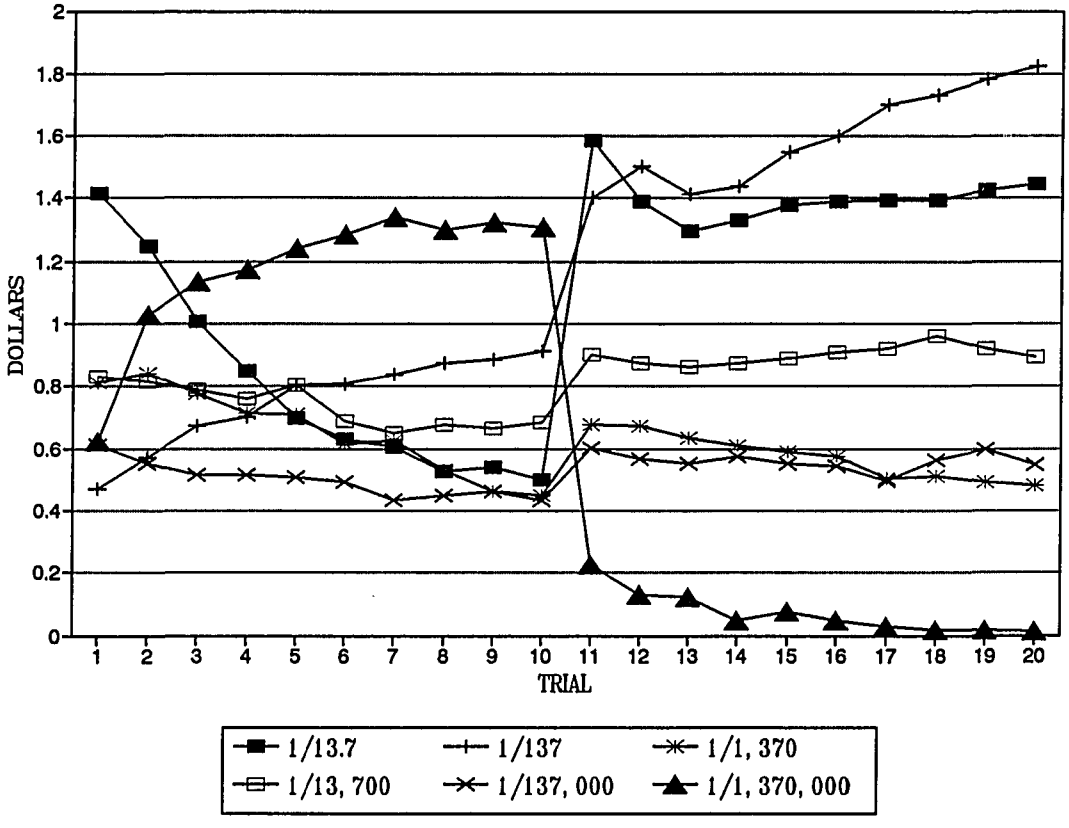

Figure 3. Average WTP of *Salmonella*: With different probability of illness

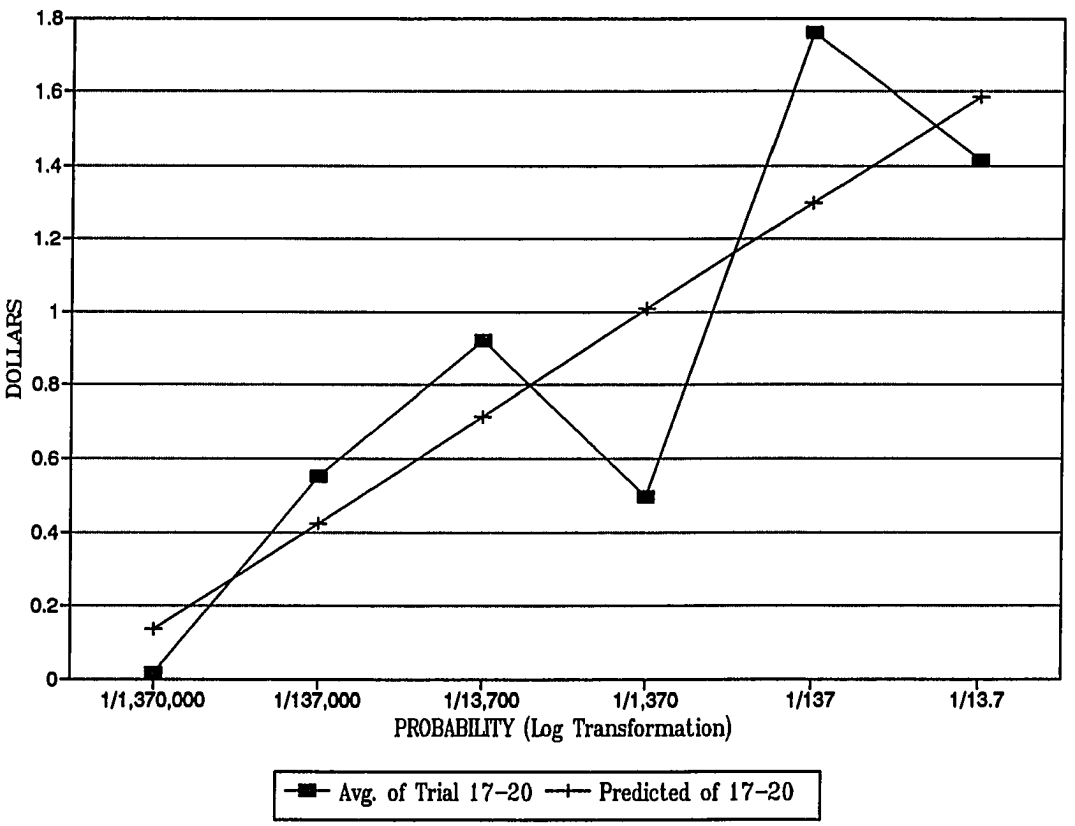

Figure 4. Average WTP of *Salmonella*: Actual and regressed WTP values

APPENDIX 1

EXPERIMENTAL INSTRUCTIONS

#____

GENERAL INSTRUCTIONS

You are about to participate in an experiment about decision making. Please follow the instructions carefully. The United States Department of Agriculture has provided funds for this research.

SPECIFIC INSTRUCTIONS

In this experiment, you will be asked to decide how much you would be willing to pay for safer food [to decide the minimum amount you would be willing to accept for taking the test product food, instead of keeping your safer food]. The experiment has two stages.

Your starting income will be $3 in stage 1. Your income will be $15 for stage 2. Your take-home income will consist of your initial income ($3 + $15) minus [plus] the value of goods purchased [the rewarded value of willingness to accept].

You will submit your bidding price on a recording card. Note only one of the trials in stage 1 will be binding and only one of the twenty trials in stage 2 will be binding. A number will be randomly selected to identify these binding trials.

You cannot reveal your bids to any other participant. Any communication between bidders during a trial will result in an automatic penalty of $3.

ABOUT YOU

1. Your sex : _____ Male _____ Female

2. Your age : ____ 19 or under
____ 20 - 24
____ 25 - 29
____ 30 - 34
____ 35 - 39
____ 40 - 44
____ 45 - 49
____ 50 or over

3. How many individuals live in your household, including yourself? ____

   If you have children, how old are they? __ __ __ __

4. Do you eat red meat? ___ Yes ___ No

   Do you eat poultry? ___ Yes ___ No

   Do you eat fish? ___ Yes ___ No

5. How often do you eat red meat, poultry, fish?

   Number of times you eat red meat per week? ____

   Number of times you eat poultry per week? ____

   Number of times you eat fish per week? ____

6. Do you eat chicken sandwiches? ____ Yes ____ No

7. Have you ever had food poisoning?

   ____ Yes ____ No ____ Don't know

8. If you became sick with a food-borne disease, how much money would you lose per day in addition to medical costs (i.e., lost wages)?

   _____ dollars per day

   _____ If you have sick leave benefits still indicate what your wage rate on this line.

CONSENT FORM

#____

You are about to participate in an experiment in willingness-to-pay [willingness-to-accept] for food safety [risk]. The purpose is to gain insight into what you are willing to pay for the guarantee that a food product will be safe [willing to accept for bearing the risk of foodborne illness in test product].

We need your signed consent if you are to act as a subject. Your participation in the experiment is completely voluntary and you may withdraw from the experiment at any time without prejudice to you. Results from the experiment will be strictly confidential. Any name associated with the experiment will be deleted upon completion of the experiment.

If you consent to participate in the experiment, please sign the consent form below.

I have read the consent form statement and agree to act as subject in the experiment, with the understanding that I can withdraw from the experiment at any time without prejudice to me.

_____ / / _____

Signature Date

STAGE 1 #____

Step 1 : You <u>own</u> the candy [candy bar] free in front of you. Your initial income is $3.

Step 2 : Let's say you are willing to [would] pay $X for the piece of candy [candy bar] and $Y for a candy bar [a piece of candy]. The <u>difference</u> ($Y - $X) [($X - $Y)] is what you are willing to pay [the minimum amount that you are willing to accept] to upgrade [trade] your piece of candy [candy bar] into [for] a candy bar [piece of candy].

Please indicate your willingness to pay [your minimum willingness to accept] to trade the piece of candy [candy bar] for a candy bar [a piece of candy]. Do <u>not</u> state what you would pay [accept] for an entire candy bar [piece of candy]. Only state the <u>difference</u> ($Y - $X) [($X - $Y)]you are willing to pay [accept].

Step 3 : Please write your bid (difference) for the <u>one</u> candy bar [piece of candy] on the recording card. The monitor will announce the highest [lowest] bidder and display the price of the candy bar (<u>second-highest [second-lowest] bidding price</u>) on the blackboard.

Note : For example, if the highest [lowest] bid was $$\alpha$$ and the second-highest [second-lowest] bid was $$\beta$$, the highest [lowest] bidder would receive [take] the candy bar [the piece of candy] and must pay [will receive] $$\beta$$.

Step 4 : There will be five trials.

Step 5 : Only one trial will be binding. After the five trials, a number will be randomly selected to determine which trial is binding. The highest [lowest] bidder of that trial will exchange the piece of candy [the candy bar] for the candy bar [the piece of candy] and must pay [will receive] the displayed price (i.e., <u>the second-highest [second-lowest] bid</u>).

Note : In the event that there is a tie for the highest [lowest] bid, those participants will be asked to bid again.

Questions

Please answer the following questions, which are designed to help you understand stage 1. Do not hesitate to ask the researchers if you have questions.

1. Suppose that person A is the highest [lowest] bidder in the first trial, person B is the highest [lowest] bidder in third trial, and person C is the highest [lowest] bidder in fifth trial. If, after five trials are finished, we randomly select the third trial, then who will trade the piece of candy [candy bar] for the candy bar [the piece of candy] ?

   _____

2. If your $\$\alpha$ bid is the highest [lowest] in the third trial, and the second-highest [second-lowest] bid is $\$\beta$, what price will you pay [receive] for the candy bar [the piece of candy] ?

   $_____

3. If your bid is not the highest [lowest] in the third trial, which is randomly selected, how much should [will] you pay [receive] for the piece of candy [candy bar] ?

   $_____

STAGE 2 #____

Step 1 : There are two types of food. The features of each are described below.

Test Product

This food has a typical chance of being contaminated with the food-borne pathogen Salmonella; i.e., it is purchased from a local source.

Stringently Screened

This food has been subjected to stringent screening for Salmonella. There is a 1 in 100,000,000 chance of getting salmonellosis from consuming this food.

Step 2 : You own a test product sandwich [a stringently screened] free in front of you. Everyone has the same test [stringently screened] sandwich. You also have initial income, $15.

Step 3 : Let's say you willing to pay $X for the test product sandwich and $Y for the stringently screened sandwich. The difference ($Y - $X) is what you are willing to pay to reduce the risk of illness from the food-borne pathogens. [Let's say $Y is the minimum amount that you are willing to accept to bear the risk of illness from the food-borne pathogens that might be contained in the test product sandwich, instead of keeping your stringently screened sandwich].

Please indicate your willingness to pay [indicate the amount of your minimum willingness to accept] to reduce [to bear] the risk of illness. Do not state what you would pay for the entire stringently screened sandwich. Only state the difference ($Y - $X) you are willing to pay.

The highest [lowest] bidder will upgrade [trade] his or her test product [stringently screened] sandwich for the stringently screened [test product] sandwich. He or she will pay [receive] the second-highest [second-lowest] bidder's price.

Step 4 : There will be twenty trials.

Step 5 : After all twenty trials are complete, we will randomly select one binding trial to determine who buys [will have] the stringently screened [the test product] food.

Note : The sandwich has to be eaten to leave with the take-home income.

Questions

Please answer the following questions, which are designed to help you understand stage 2. Do not hesitate to ask the researchers if you have questions.

1. There are twenty bidding trials. If person A is the highest [lowest] bidder in the first trial, person B is the highest [lowest] bidder in the eighteenth trial, and the eighteenth trial is selected, then who will receive the stringently screened [test product] food? _____

2. If your $\$\alpha$ bid is the highest [lowest] in the eighteenth trial, and the second highest [second lowest] bid is $\$\beta$, what price will you pay [receive] for the stringently screened [test product] food? $_____

NOTE : Please answer the questions below.

1. What do you think is the chance of becoming ill from Salmonella, given that you eat an average amount of typical food products in the United States over one year?

   Answer: _____ chance out of 1 million people

2. What do you think are the important sources of the food-borne pathogen, Salmonella, in the United States?

   Please list the type of food items.

   _____ _____ _____

AGREEMENT OF UNDERSTANDING FORM

#____

The risks you took in eating this food are identical to those you take when eating meals you prepare at home or purchase when eating out.

Please sign below to indicate that you have read and understood the above announcement.

_____/___/____

Signature Date

APPENDIX 2

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 125,143 chance that you will become ill from Campylobacter.

Stringently Screened

This food has been subjected to stringent screening for Campylobacter. There is a 1 in 100,000,000 chance of getting Campylobacteriosis from consuming this food.

Description of Campylobacteriosis :

Symptoms are those of a intestinal disease with acute diarrhea and severe abdominal pains. Diarrhea is preceded by brief fever and malaise. The actual individual chance of infection of Campylobacteriosis is 1 in 114 annually. Of those individuals who get sick, 1 individual out of 1,000 will die annually. The average cost for medical expenses and productivity losses from a mild case of Campylobacterisosis is $230.

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 137,000 chance that you will become ill from Salmonella.

Stringently Screened

This food has been subjected to stringent screening for Salmonella. There is a 1 in 100,000,000 chance of getting Salmonellosis from consuming this food.

Description of Salmonellosis :

Symptoms are those of a mild "flu-like" intestinal disease of short duration with abdominal pains, nausea, vomiting, and diarrhea. The actual individual chance of infection of Salmonellosis is 1 in 125 annually. Of those individuals who get sick, 1 individual out of 1,000 will die annually. The average cost for medical expenses and productivity losses from a mild case of Salmonellosis is $220.

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 173,694 chance that you will become ill from Staphylococcus aureus.

Stringently Screened

This food has been subjected to stringent screening for Stapylococcus aureus. There is a 1 in 100,000,000 chance of getting Staphylococcal food poisoning from consuming this food.

Description of Staphylococcal food poisoning :

Symptoms are nausea, vomiting, abdominal pains, and diarrhea. The actual individual chance of infection of Staphylococcal food poisoning is 1 in 159 annually. Of those individuals who get sick, 1 individual out of 1,250 will die annually. The average cost for medical expenses and productivity losses from a case of Staphylococcus aureus is $600.

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 2,628,000 chance that you will become ill from Trichinella.

Stringently Screened

This food has been subjected to stringent screening for Trichinella. There is a 1 in 100,000,000 chance of getting Trichinellosis from consuming this food.

Description of Trichinellosis :

Symptoms are intestinal disease with nausea, vomiting, abdominal pain, and diarrhea in intestinal maturation phase. During muscular migration, it begins with edema of the upper eyelids, headaches, fever and sweating and chills. The actual individual chance of infection of salmonellosis is 1 in 2,400 annually. Of those individuals who get sick, 1 individual out of 100 will die annually. The average cost for medical expenses and productivity losses from a case of Trichinellosis $2,485.

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 26,280,000 chance that you will become ill from Clostirdium perfringens.

Stringently Screened

This food has been subjected to stringent screening for Clostridium perfringens. There is a 1 in 100,000,000 chance of getting Clostridial food poisoning from consuming this food.

Description of Clostridial food poisoning :

Symptoms are acute intestinal disease of short duration with abdominal pains and diarrhea. The actual individual chance of infection of Clostridial food poisoning is 1 in 24,000 annually. Of those individuals who get sick, 1 individual out of 100 will die annually. The average cost for medical expenses and productivity losses from a case of Clostridial food poisoning is $5,100.

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 46,585 chance that you will become ill from food-borne illnesses.

Stringently Screened

This food has been subjected to stringent screening for food-borne pathogens. There is a 1 in 100,000,000 chance of getting food-borne illnesses from consuming this food.

Description of Food-borne Illnesses :

Symptoms are those of a intestinal disease with abdominal pains, nausea, vomiting, and diarrhea. The actual individual chance of infection of food-borne illness is 1 in 43 annually. Of those individuals who get sick, 1 individual out of 44 will die annually. The average cost for medical expenses and productivity losses from a case of food-borne illness is $374.

SECTION II.

EXPERIMENTAL SUPPORT FOR HANEMANN'S CONJECTURE ON THE DIVERGENCE BETWEEN WTP AND WTA MEASURES OF VALUE

ABSTRACT

We provide experimental support for Hanemann's conjecture that the divergence of willingness to pay (WTP) and willingness to accept (WTA) is driven by the elasticity of substitution between goods. For a market good with close substitutes (candy bar), our results indicate a convergence of WTP and WTA measures of value. In contrast, for a nonmarket good with imperfect substitutes (health), the divergence of WTP and WTA value measures is persistent, even with repeated market exposure and full information on the nature of the good.

INTRODUCTION

Over the past decade, a consistent and frustrating pattern of empirical evidence has accumulated suggesting a significant divergence between willingness to pay (WTP) and willingness to accept (WTA) measures of value. Field-contingent valuation studies first uncovered the pattern and laboratory markets have confirmed that the divergence is persistent [see, for example, Judd Hammack and Gardner M. Brown, Jr. (1974), Robert D. Rowe et al. (1980), Jack L. Knetsch and John A. Sinden (1984), and David S. Brookshire and Don L. Coursey (1987)]. The divergence is troubling in that standard theory predicts that with small income effects WTP and WTA should be equivalent [see Robert Willig (1976)]. The evidence that they are not suggests a need to reexamine the analytical foundations of value measures.

In response, Michael W. Hanemann (1991) has offered a straightforward explanation of why divergence occurs and by how much. By expanding traditional theory to include both substitution and income effects, Hanemann demonstrated that the divergence can range from zero to infinity, depending on whether the elasticity of substitution between goods is infinite or zero, given positive income elasticity. Hanemann proposed that we should expect convergence of WTP and WTA value measures when the good in question has a perfect substitute. When the good has an imperfect substitute, a value divergence will exist and will expand as the elasticity of substitution decreases.

This paper tests Hanemann's proposition in an nonhypothetical experimental

auction market. Our results strongly support his argument. We find that, for a private-market food product with a relatively close substitute, the divergence of WTP and WTA value measures disappears with repeated exposure to the market. In contrast, for a private nonmarket good with no close substitute, the divergence is robust and persistent, even given repeated market exposure and full information on the dimensions of the good. These results suggest that the elasticity of substitution may prove to be a key to unlocking the troubling divergence of value measures.

This paper proceeds as follows. Section 1 describes our general experimental design in terms of Hanemann's proposition. Sections 2 and 3 outline the experimental procedures and results, respectively. Our conclusions are offered in Section 4.

HANEMANN'S PROPOSITION AND GENERAL EXPERIMENTAL DESIGN

Figure 1 illustrates the simple analytics of Hanemann's argument [also see Elizabeth Hoffman and Matthew Spitzer (1990)]. Part (a) of Figure 1 presents the case in which goods X and Y are perfect substitutes, i.e., the elasticity of substitution is infinite. Let the individual start at point A with endowments of X_0 and Y_0. If the individual's endowment of X_0 is increased to X_1, then the maximum he or she would be willing to pay for this change is the distance AB, or the compensating surplus. The minimum he or she would be willing to accept not to change is AC, or the equivalent surplus. Given perfect substitutability between X and Y, AB equals AC. Therefore, given a positive income elasticity, we should expect to see convergence of WTP and WTA measures of value.

Part (b) of Figure 1 presents the case in which X and Y are imperfect substitutes. The individual is again willing to pay $A'B'$ to secure the change. Note that $A'B'$ equals AB. Now, however, the individual must receive $A'C'$ not to change. Hanemann rigorously demonstrated that $A'C'$ exceeds $A'B'$ and that this divergence expands as the elasticity of substitution between X and Y decreases.

To test Hanemann's proposition, we used the following general experimental design in which both a nonhypothetical market good and a nonhypothetical nonmarket good were auctioned off using either the WTP or WTA measures of value. Similar to Daniel Kahneman et al. (1990), we auctioned off a brand-name candy bar to compare WTP and WTA value measures for a market good with

relatively close substitutes. Our hypothesis was that the subjects would have a relatively high elasticity of substitution for the candy bar and all other composite commodities as represented by wealth. If Hanemann is correct, then the WTP and WTA measures of value will converge. If the value measures do not converge, then there is further support for Kahneman et al.'s argument of a fundamental "endowment" effect in the theory of choice [also see Jack Knetsch (1989)]. The endowment effect can be interpreted as existing when the individual becomes attached to the good, thereby causing the subject to demand a higher level of compensation than he or she was originally willing to pay.

To compare the case of imperfect substitutes, we auctioned off a nonmarket good as represented by reduced health risk from food-borne pathogens. Our hypothesis was that the subjects would have a relatively low elasticity of substitution between health and all other composite commodities as represented by wealth. Again, if Hanemann is correct, then our ex ante expectation is that the WTA measures should be significantly greater than the WTP measures. Given our experimental design, we now restate Hanemann's proposition as follows.

> **Convergence Proposition:** Given positive income elasticity, the WTP and WTA measures of value will converge for the market good with close substitutes (candy bar), but will not converge for the nonmarket good with imperfect substitutes (health risk from food-borne pathogens).

If we can reject the convergence proposition, then we cannot support Hanemann's argument. In this case, other explanations such as the endowment effect or loss aversion become more attractive. If we cannot reject the proposition, however, then we can offer support to the conjecture that the elasticity of substitution is a key to understanding the convergence or divergence between WTP and WTA measures of value.

EXPERIMENTAL PROCEDURES

The experiment was divided into two stages. Stage 1 was the market good auction. Stage 2 was the nonmarket good auction. Subjects participated in both stages either for the WTP or WTA experiment. We will discuss each stage in more detail for the WTP experiment. See the Appendix for the instructions for the WTP experiment. The WTA experiment was identical to the WTP experiment in all aspects except for the value measure and initial ownership of the good.

In Stage 1, each subject was provided an initial income of $3 and a small piece of candy. To facilitate learning and value formation, the auction was repeated over five trials. The number of trials was selected after extensive pretesting to determine how quickly individual value measures stabilized. Note that to control wealth effects, we made the subjects fully aware that only one of the five trials was binding. The binding trial was selected at random by a Monte Carlo number generator on a personal computer. In an attempt to accurately elicit preferences, we used a Vickrey second-price sealed-bid auction [see William Vickrey (1961)]. The Vickrey auction has been successfully used to elicit values in various experimental settings [see Don L. Coursey (1987) and Jason F. Shogren (1990)].

The market good was a regular-size brand-name candy bar. Each subject was asked the maximum he or she would be willing to pay to upgrade the small piece of candy to the brand-name candy bar. For each trial, each subject recorded a bid on a recording card that was collected by the monitor. The highest bidder's identification

number and the reigning price (the second-highest bid) were posted as public information on a blackboard.

Stage 2 was the nonmarket good auction. The procedures were similar to those in Stage 1 with some noted exceptions. An initial income of $15 was provided to each participant. Two types of food items were then shown to the subjects with a description of each item. The first type was the test product. The test product represented food purchased from a local source with a typical chance of being contaminated with a food-borne pathogen from one-time consumption. Five food-borne pathogens were considered in five separate experimental sessions: *Campylobacter, Salmonella, Staphylococcus aureus, Trichinella spiralis* and Clostridium perfringens.[1] All five pathogens occur in the United States. The test product was provided to every participant as a free lunch. The second food type was stringently screened food. The stringently screened food had been tested for food-borne pathogens and had a low probability (1 in 100 million) of causing food-borne illness.

Each participant was then asked the maximum he or she would be willing to pay to upgrade the test product to the screened food product. The bidding procedure was the same as that used in Stage 1 except that there were twenty trials in Stage 2. "Naive" bids were elicited in the first ten trials. The bids were naive in that the subjects were not given any information on the actual probabilities of contracting a food-borne illness from consuming the typical food product. After the tenth trial, the

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[1]We report results for all five pathogens because measures of consumers' WTA and WTP to reduce or eliminate these pathogens are interesting in their own right. See Tanya Roberts and David Smallwood (1991).

monitor supplied three items of information: (a) the actual probability of becoming ill from eating a year's supply of the typical food product; (b) a description of the severity of the illness; and (c) the symptoms and average medical cost of a mild case of infection. For *Salmonella*, the following information was provided [see John V. Bennett et al. (1987) and Tanya Roberts (1989)].

> Description of Salmonellosis :
>
> > Symptoms are those of a mild flu-like intestinal disease of short duration with abdominal pains, nausea, vomiting, and diarrhea. The actual individual chance of infection of salmonellosis is 1 in 125 annually. Of those individuals who get sick, 1 individual out of 1,000 will die annually. The average cost for medical expenses and productivity losses from a mild case of salmonellosis is $220.

Given this information, "informed" bids were elicited in trials 11 through 20.

The computer randomly selected one of the twenty trials as binding. The highest bidder paid the displayed second-highest bidding price and ate the stringently screened food. The highest bidder's take-home income was $15 minus the price paid for the screened food product. The other bidders ate the test product and took home $15. Note that the subjects had to eat the food item to leave the experiment with the take-home income.

Table 1 summarizes the experimental design for both the WTP and the WTA experiments. One hundred and forty-two subjects participated in the experiment. All were undergraduate and graduate students from Iowa State University (ISU), recruited campuswide. Note that a subject participated in either the WTA or the

WTP experiment, not both. Also, each subject was only confronted with one food-borne pathogen, not all five, regardless whether he or she was in the WTA or the WTP experiment. After each subject read the instructions and answered a set of questions to test his or her understanding of the experiment and the monitor answered all relevant questions, the experiment began. All experiments were conducted in the ISU meat testing laboratory with modern kitchen facilities. The ISU meat lab conducts food tasting experiments on a regular basis. The lab is actively involved in all aspects of meat processing and handling, thereby providing a unique setting for our experiment.

RESULTS AND DISCUSSION

Overall, we cannot reject the convergence proposition. Table 2 and Figure 2 illustrate that the WTP and WTA measures of value for the market good were not significantly different, with the exception of the first trial. Repeated exposure to the auction market caused the values to converge [also see Don L. Coursey et al. (1987)]. Trial 1 represents the inexperienced one-shot bid analogous to the contingent valuation method. The average WTP-WTA difference in the one-shot bid equaled 11 cents, and the null hypothesis that WTP and WTA were equal is rejected at the 5 percent significance level. The value disparity converged, however, to a difference of 6 cents in trial 2, which is not statistically significant. By trials 3, 4, and 5, the average WTP and WTA values converged to differences between 1 cent and 3 cents. We cannot reject the equality of the WTP and WTA measures.

Tables 3 and 4 and Figures 3 through 7 illustrate that the majority of the WTA measures for the nonmarket good significantly exceed the WTP measures. This holds for both the naive bids (trials 7 through 10) and the informed bids (trials 17 through 20). Note that the WTP and WTA measures for each pathogen are examined with the two mean values: without elimination of the highest and lowest bids and with elimination. We consider elimination to explore Robin Gregory and Lita Furby's (1987) argument that values are extremely sensitive to one or two outliers [also see Robert C. Mitchell and Richard T. Carson (1989)]. They reexamined Coursey et al.'s sucrose octa-acetate (SOA) experiment with elimination

of outliers and found that the results of value convergence depend on inclusion of the outlier. To illustrate the robustness of our results, we consider values with and without the elimination of outliers.

Means of the WTP experiment without elimination closely coincided with those with elimination. In the WTA experiment, outliers change the majority of the mean values, especially for *Salmonella*, *Staphylococcus aureus*, and *Trichinella spiralis*. For the initial one-shot bid in trial 1, we observed extremely high WTA values. For *Salmonella*, the mean WTA is more than thirteen thousand times greater than the mean WTP without elimination and is still three thousand times greater with elimination. WTA for *Clostridium perfringens* is forty-seven times greater than WTP without elimination. WTA divergence for the other pathogens ranges from four to thirty four times greater than that for WTP. For the initial one-shot bid, we performed a one-tail t-test and the Mann-Whitney rank-sum *U*-test to test the significance of the divergence between WTP and WTA. According to the rank-sum test, the null hypothesis of all pathogens that WTP and WTA values are from the same parental population is rejected at the 5 precent significance level.

For most of the naive bids (trials 7 through 10), the average bidding prices stay relatively constant in both the WTP and the WTA bids. This result is consistent with Coursey's observation that Vickrey auctions usually stabilize by the sixth or seventh trial. The mean WTA for trials 7 through 10 ranges from approximately three times greater than that of the mean WTP for *Campylobacter* to approximately eighteen times greater than that of the mean WTP for *Salmonella* without

elimination. With elimination, the results indicate that the mean WTA is two to six times greater than the mean WTP. The disparities between WTP and WTA for each pathogen are tested by performing a multivariate analysis[2] and a *U*-test. Although the WTP and WTA experiments are statistically independent, we used multivariate analysis to account for the between-trial correlation among bids from the same subjects. The difference between WTP and WTA in the naive trials indicates that most pathogens are significantly different between WTP and WTA by t-test, both with and without elimination. The *Salmonella* experiment is statistically insignificant by t-test without elimination, but significant with elimination.

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[2]Let X_{ijk} be the subject's k^{th} bid in the j^{th} trial of i^{th} group.
$i = 1, 2$ ($i = 1$, WTP experiment; $i = 2$, WTA experiment)
$j = 7, 8, 9, 10$ (trial)
$k = 1, 2, \ldots, n_i$ (number of subjects in experiment)
Because X_{ijk} and $X_{ij'k}$ $(j \neq j')$ are not independent (measured repeatedly), multivariate analysis or split plot design can be applied.

Suppose vector $\mathbf{X}_i \equiv (X_{i,7}, X_{i,8}, X_{i,9}, X_{i,10})'$ $(i = 1, 2) \sim \text{MVN}(\boldsymbol{\mu}_i, \boldsymbol{\Sigma}_i)$
where $\boldsymbol{\mu}_i = (\mu_{i,7}, \ldots, \mu_{i,10})'$

$$\boldsymbol{\Sigma}_i = \begin{bmatrix} \text{Var}(X_{i,7}) & \text{Cov}(X_{i,7}, X_{i,8}) & \text{Cov}(X_{i,7}, X_{i,9}) & \text{Cov}(X_{i,7}, X_{i,10}) \\ & \text{Var}(X_{i,8}) & \text{Cov}(X_{i,8}, X_{i,9}) & \text{Cov}(X_{i,8}, X_{i,10}) \\ & & \text{Var}(X_{i,9}) & \text{Cov}(X_{i,9}, X_{i,10}) \\ & \text{Symmetry} & & \text{Var}(X_{i,10}) \end{bmatrix}$$

Consider $Y_i \equiv \mathbf{a}'\mathbf{X}_i$ where $\mathbf{a}' = \frac{1}{4}(1, 1, 1, 1)'$ $(i = 1, 2)$. Then $Y_1 = \frac{1}{4}(X_{1,7} + X_{1,8} + X_{1,9} + X_{1,10})$ and $Y_2 = \frac{1}{4}(X_{2,7} + X_{2,8} + X_{2,9} + X_{2,10})$ are normally distributed with mean $\mathbf{a}'\boldsymbol{\mu}_1$, $\mathbf{a}'\boldsymbol{\mu}_2$ and variance $\mathbf{a}'\boldsymbol{\Sigma}_1\mathbf{a}$, $\mathbf{a}'\boldsymbol{\Sigma}_2\mathbf{a}$, respectively. Because Y_1 and Y_2 are independent, $(Y_1 - Y_2)$ is normally distributed with mean $(\mathbf{a}'\boldsymbol{\mu}_1 - \mathbf{a}'\boldsymbol{\mu}_2)$ and variance $(\mathbf{a}'\boldsymbol{\Sigma}_1\mathbf{a} + \mathbf{a}'\boldsymbol{\Sigma}_2\mathbf{a})$. There are n_1, n_2 samples from the WTP and the WTA experiments, respectively (i.e., using $y_{1,1}, \ldots, y_{1,n_1}$ and $y_{2,1}, \ldots, y_{2,n_2}$).

To test the null hypothesis that there is a difference between the WTP and WTA experiments, we can use the t-test for the difference of the mean between the WTP and WTA experiments. [see Richard A. Johnson and Dean W. Wichern (1988)].

For the informed bids (trials 17 through 20), we observed that bids initially increased from the information shock. The WTP experiments have a smaller increase relative to the WTA experiments. Again, after six trials with information, the mean WTP bid stabilizes. Mean WTA bids converge to lower values, with some variation in the last two or three trials. For trials 17 through 20, the differences between WTP and WTA range from three to five times in *Salmonella, Campylobacter,* and *Clostridium perfringens*. The WTP and WTA bids for these three pathogens are statistically significant with and without elimination. *Staphylococcus aureus* and *Trichinella spiralis* bids also are significantly different, both with and without elimination.

In sum, we cannot reject the convergence proposition. For the market good with close substitutes, WTP and WTA measures of value are not statistically different with repeated market exposure. In contrast, for the nonmarket good with imperfect substitutes, WTP and WTA measures are significantly different, even after repeated market exposure and with full information about the probability and severity of the health risk. Our results support Hanemann's proposition that the elasticity of substitution drives the divergence between value measures. The opportunity to substitute goods may be the underlying motivation behind Kahneman et al.'s observations of an endowment effect. They recognize this possibility, stating that ". . . endowment effects will almost certainly occur when owners are faced with an opportunity to sell an item purchased for use that is not easily replaceable" (p. 1344). If the endowment effect was not driven by substitutability, then we should have observed a divergence in value measures for the candy bar, which we did not.

CONCLUSIONS

The divergence in WTP and WTA measures of value has troubled economists for the past decade. The divergence even lead Ronald G. Cummings et al. (1986) to recommend in their Reference Operating Conditions (pp. 102-109) for contingent valuation that only WTP measures be elicited in the attempt to value nonmarket goods. Hanemann has offered an explanation grounded in economic theory, however, that may calm the fears that the divergence is some form of cognitive mistake. Our experimental results support his conjecture. For a market good with close substitutes (candy bar) we find that WTP and WTA value measures converge. In contrast, for a nonmarket good with no close substitutes (health risk), the value measures diverge and persist, even with repeated market exposure and full information on the nature of the good. We support the argument that the relative elasticity of substitution may well drive WTP-WTA value discrepancies.

The next steps to be taken are twofold. First, researchers should replicate our experiment to test the robustness of our findings. More evidence to support or contradict our findings will be most welcome. Second, if Hanemann is correct, then researchers should concentrate on better understanding the nature of substitutability when we move outside the lab to field studies of nonmarket valuation.

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TABLES AND FIGURES

Table 1. Summary of experimental design

PROCEDURE	EXPERIMENT	
	WILLINGNESS TO PAY (WTP)	WILLINGNESS TO ACCEPT (WTA)
STAGE 1 - Market good - 5 trials - Vickrey second-price sealed-bid auction - 1 trial binding	Initial conditions - $3 income - Small piece of candy Auctioned good - Regular-size brand-name candy bar Value measure WTP (compensating surplus) to exchange piece of candy for candy bar	Initial conditions - $3 income - Regular-size brand-name candy bar Auctioned good - Small piece of candy Value measure WTA (equivalent surplus) to exchange candy bar for small piece of candy
STAGE 2 - Nonmarket good - 20 trials 10 naive 10 experienced - 1 trial binding - Vickrey auction - 5 food-borne pathogens • *Campylobacter* • *Salmonella* • *Staphylococcus aureus* • *Trichinella spiralis* • *Clostridium perfringens*	Initial conditions - $15 income - Typical food product with average health risk from food-borne pathogen Auctioned good - Stringently screened food with 1 in 100 million chance of health risk from food-borne pathogen Value measure WTP (compensating surplus) to exchange typical food product for screened food product	Initial conditions - $15 income - Stringently screened food Auctioned good - Typical food product Value measure WTA (equivalent surplus) to exchange screened food product for typical food product

Table 2. Comparison of mean of WTP and WTA in candy bar experiment

H_0: WTP = WTA
H_1: WTP < WTA

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
Mean	WTP = 0.40 (0.36)[a] WTA = 0.51 (0.35)	WTP = 0.38 (0.20) WTA = 0.44 (0.34)	WTP = 0.40 (0.23) WTA = 0.39 (0.35)	WTP = 0.40 (0.19) WTA = 0.37 (0.36)	WTP = 0.39 (0.20) WTA = 0.37 (0.35)
t-test[b]	-1.81[c]	-1.19	0.22	0.55	0.57
U-test[d]	4,047.5[c]	4,607	5,185[c]	5,342[c]	5,332.5[c]

Note: The sample size for the WTP experiments was n = 68; sample size for the WTA experiment was n = 74.

[a]Sample standard deviations are in parentheses.

[b]One-tail t-test.

[c]Denotes rejection of H_0 at the 1 percent significance level for the t-test and *U*-test.

[d]Mann-Whitney *U*-test.

[e]Denotes rejection of H_0 at the 5 percent significance level for the t-test and *U*-test.

Table 3. Comparison of WTP and WTA of five pathogens without eliminaiton

Pathogen (Probability of Illness)	H_0: WTP = WTA H_1: WTP < WTA								
	Inexperienced One-Shot (1st Trial)			Naive (7th-10th Trials)			Informed (17th-20th Trials)		
	Mean	t-test[a]	*U*-test[b]	Mean	t-test	*U*-test	Mean	t-test	*U*-test
Campylobacter (1/125,143)	WTP = 0.60 (0.50)[c] WTA = 5.06 (4.55)	-3.65[d]	141[d]	WTP = 0.71 (0.43) WTA = 2.36 (3.89)	-1.57[e]	201	WTP = 0.86 (0.38) WTA = 3.03 (4.39)	-1.84[d]	228
Salmonella (1/137,000)	WTP = 0.61 (0.53) WTA = 8029 (25957)	-1.20	136.5[d]	WTP = 0.44 (0.23) WTA = 8.01 (25.46)	-1.15	120[d]	WTP = 0.55 (0.25) WTA = 1.62 (2.00)	-2.04[d]	156[d]
Stapylococcus aureus (1/173,694)	WTP = 0.97 (0.39) WTA = 5.55 (7.86)	-2.25[d]	140[d]	WTP = 0.92 (0.32) WTA = 3.89 (8.19)	-1.40[d]	187	WTP = 0.84 (0.33) WTA = 56.2 (205.87)	-1.04	170.5
Trichinella spiralis (1/2,628,000)	WTP = 0.48 (0.42) WTA = 12.8 (24.80)	-1.93[d]	115[d]	WTP = 0.69 (0.46) WTA = 10.51 (25.36)	-1.50[e]	155[d]	WTP = 0.81 (0.55) WTA = 18.0 (50.82)	-1.31	172.5
Clostridium perfringens (1/26,280,000)	WTP = 0.64 (0.63) WTA = 30.2 (50.56)	-2.26[d]	111[d]	WTP = 0.58 (0.41) WTA = 1.98 (1.37)	-3.77[d]	109.5[d]	WTP = 0.42 (0.33) WTA = 2.21 (1.70)	-4.00[d]	91[d]

Note: Sample sizes are as follows: *Camplyobacter* (WTP = 15, WTA = 14), *Salmonella* (WTP = 15, WTA = 15), *Stapylococcus aureus* (WTP = 12, WTA = 15), *Trichinella spiralis* (WTP = 13, WTA = 15), *Clostridium perfringens* (WTP = 13, WTA = 15).

[a]One-tail t-test.

[b]Mann-Whitney *U*-test.

[c]Sample standard deviations are in parentheses.

[d]Denotes rejection of H_0 at the 1 percent significance level for the t-test and *U*-test.

[e]Denotes rejection of H_0 at the 5 percent significance level for the t-test and *U*-test.

Table 4. Comparison of WTP and WTA of five pathogens with elimination

Pathogen (Probability of Illness)	H_0: WTP = WTA H_1: WTP < WTA								
	Inexperienced One-Shot (1st Trial)			Naive (7th-10th Trials)			Informed (17th-20th Trials)		
	Mean	t-test[a]	*U*-test[b]	Mean	t-test	*U*-test	Mean	t-test	*U*-test
Campylobacter (1/125,143)	WTP = 0.53 (0.31)[c] WTA = 4.63 (3.65)	-3.87[d]	100[d]	WTP = 0.71 (0.36) WTA = 1.50 (1.70)	-1.58[e]	150	WTP = 0.88 (0.32) WTA = 2.29 (3.02)	-1.61[e]	177
Salmonella (1/137,000)	WTP = 0.55 (0.38) WTA = 1572 (5537)	-1.02	96[d]	WTP = 0.44 (0.20) WTA = 1.49 (0.92)	-4.00[d]	91[d]	WTP = 0.56 (0.22) WTA = 1.23 (1.25)	-1.91[d]	114[d]
Stapylococcus aureus (1/173,694)	WTP = 1.02 (0.26) WTA = 4.08 (4.19)	-2.63[d]	100	WTP = 0.97 (0.21) WTA = 3.12 (7.81)	-0.99	143[e]	WTP = 0.91 (0.23) WTA = 3.33 (7.37)	-1.19	127.5
Trichinella spiralis (1/2,628,000)	WTP = 0.44 (0.31) WTA = 7.08 (5.93)	-4.03[d]	78[d]	WTP = 0.69 (0.44) WTA = 4.43 (5.79)	-2.32[d]	110[e]	WTP = 0.82 (0.51) WTA = 5.42 (7.33)	-2.26[d]	128.5
Clostridium perfringens (1/26,280,000)	WTP = 0.57 (0.49) WTA = 19.4 (19.51)	-3.47[d]	78[d]	WTP = 0.60 (0.38) WTA = 1.83 (1.14)	-3.67[d]	76.5[d]	WTP = 0.43 (0.32) WTA = 2.00 (1.34)	-4.11[d]	66[d]

Note: Sample sizes are as follows: *Camplyobacter* (WTP = 13, WTA = 12), *Salmonella* (WTP = 13, WTA = 13), *Stapylococcus aureus* (WTP = 10, WTA = 13), *Trichinella spiralis* (WTP = 11, WTA = 13), *Clostridium perfringens* (WTP = 11, WTA = 13).

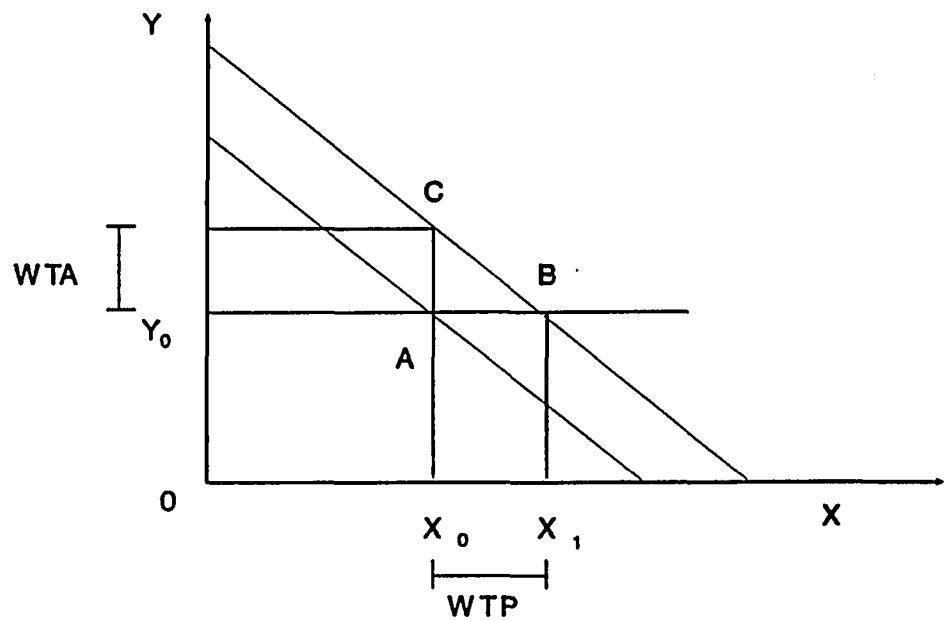
[a]One-tail t-test.

[b]Mann-Whitney *U*-test.

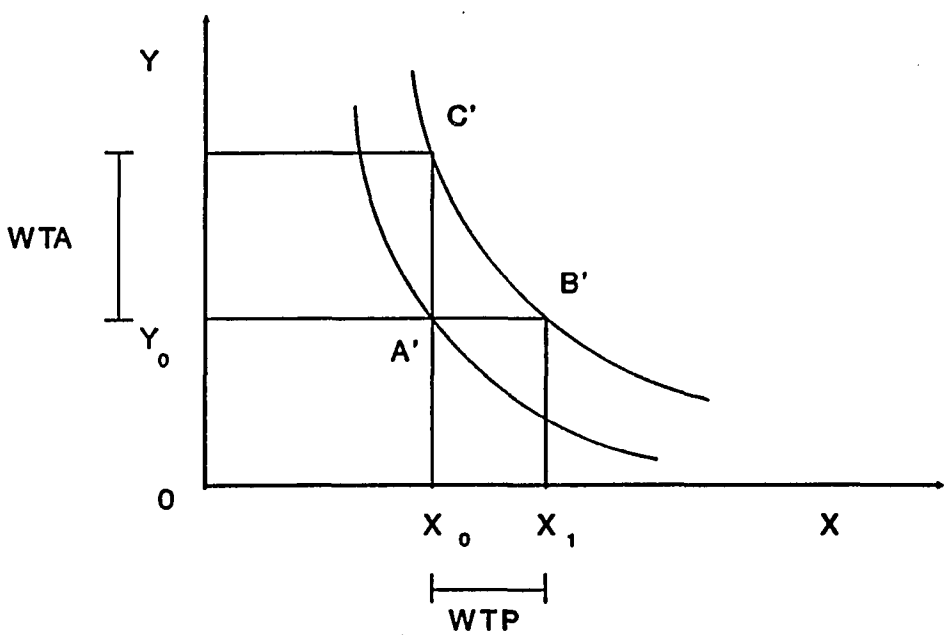
[c]Sample standard deviations are in parentheses.

[d]Denotes rejection of H_0 at the 1 percent significance level for the t-test and *U*-test.

[e]Denotes rejection of H_0 at the 5 percent significance level for the t-test and *U*-test.



(a) Perfect Substitutes



(b) Imperfect Substitutes

Figure 1. Simple analytics of WTP-WTA divergence

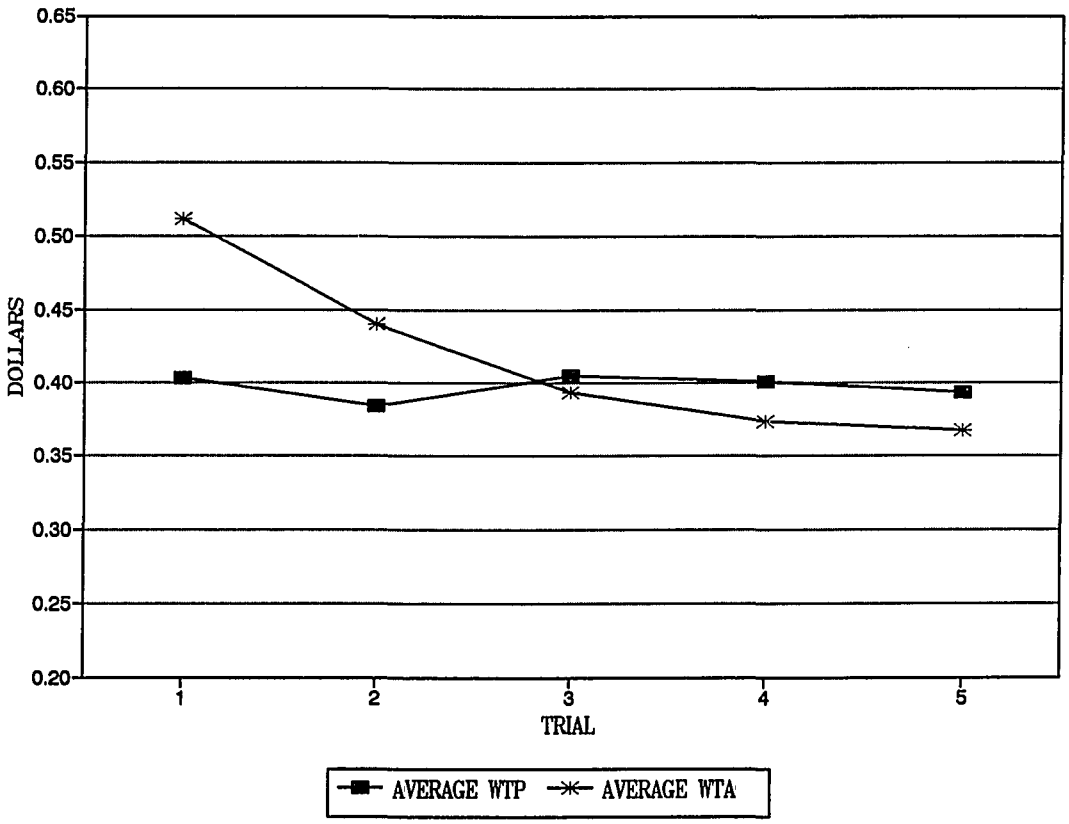


Figure 2. Comparison of WTP and WTA: Candy bar experiments

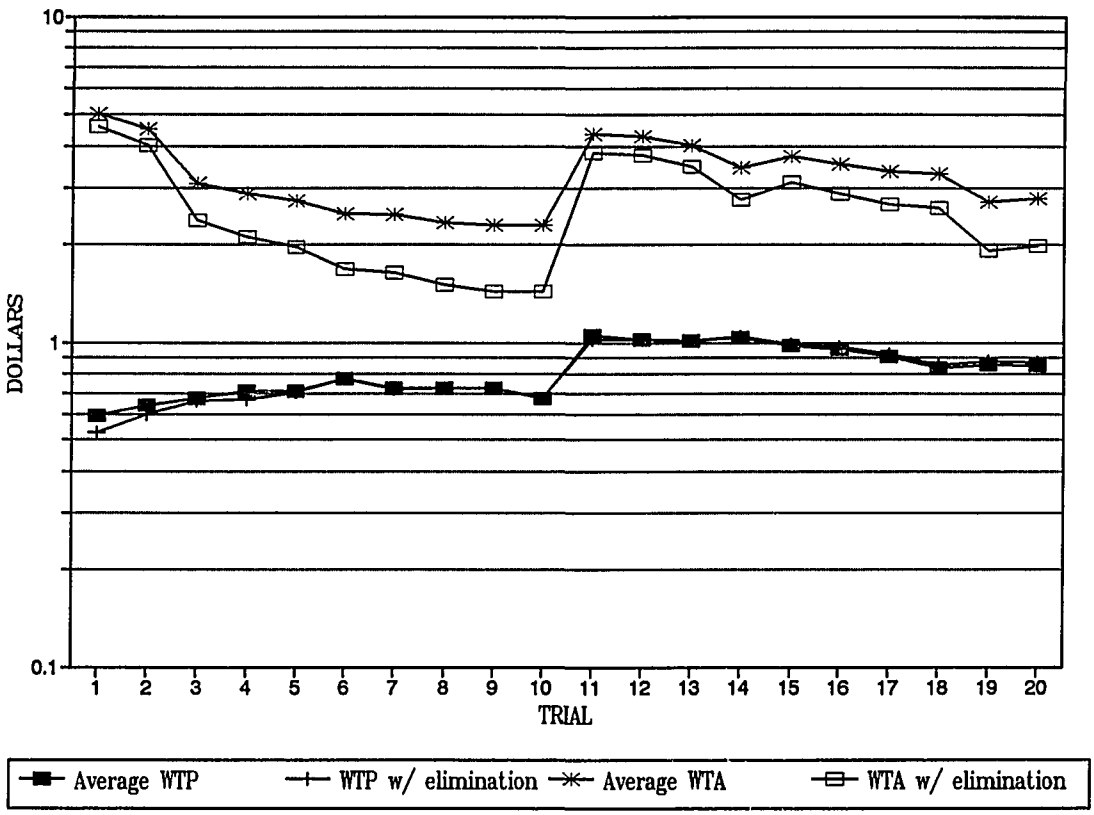


Figure 3. WTP and WTA comparison: *Campylobacter*

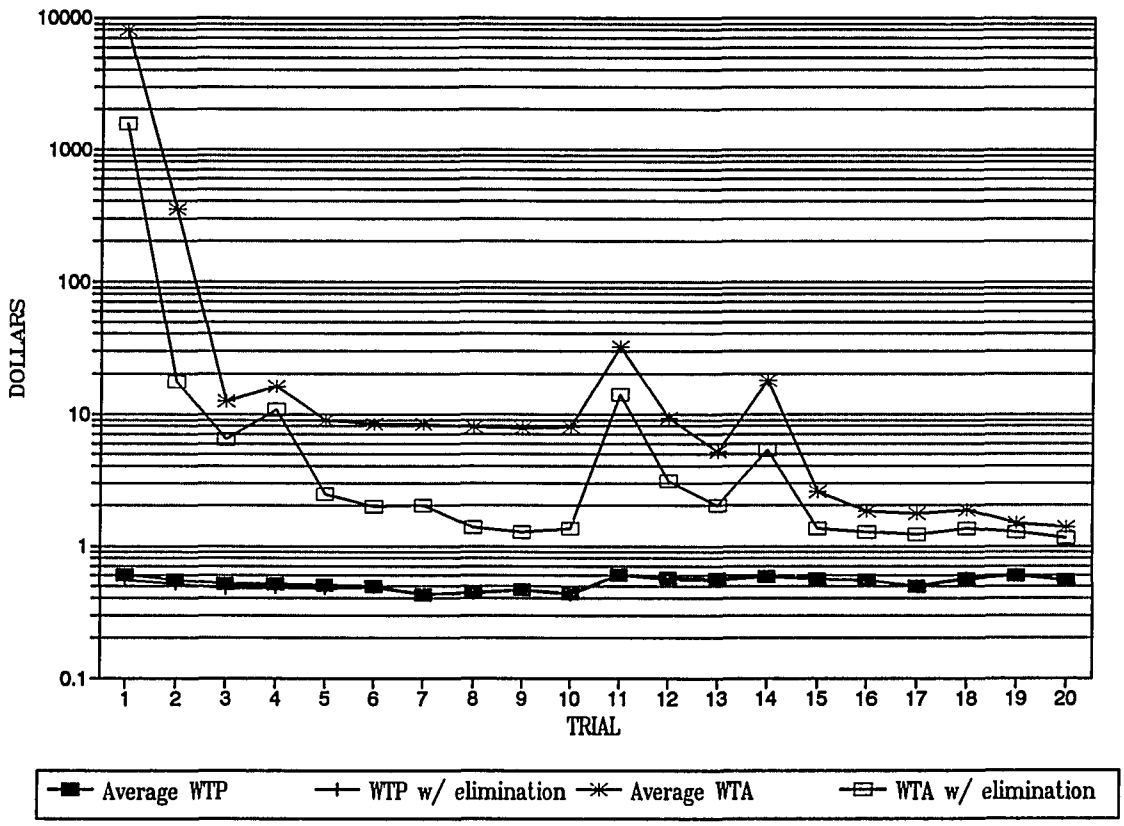


Figure 4. WTP and WTA comparison: *Salmonella*

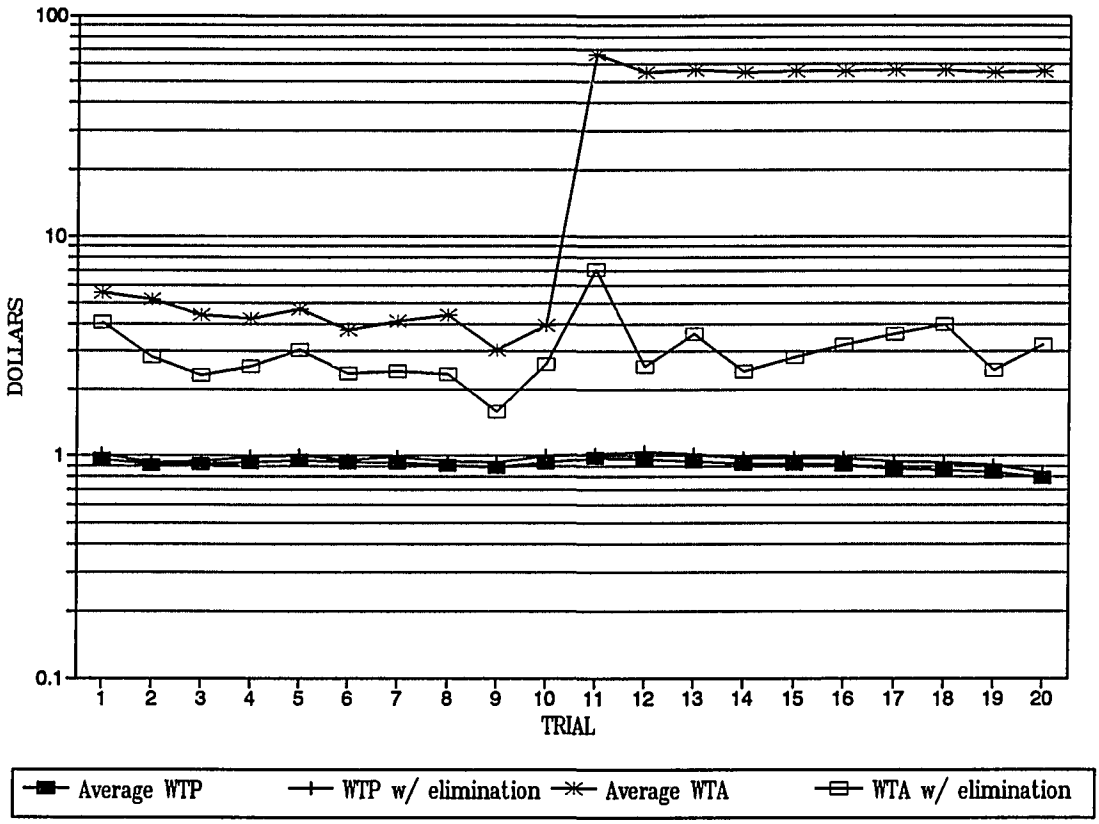


Figure 5. WTP and WTA comparison: *Staphylococcus aureus*

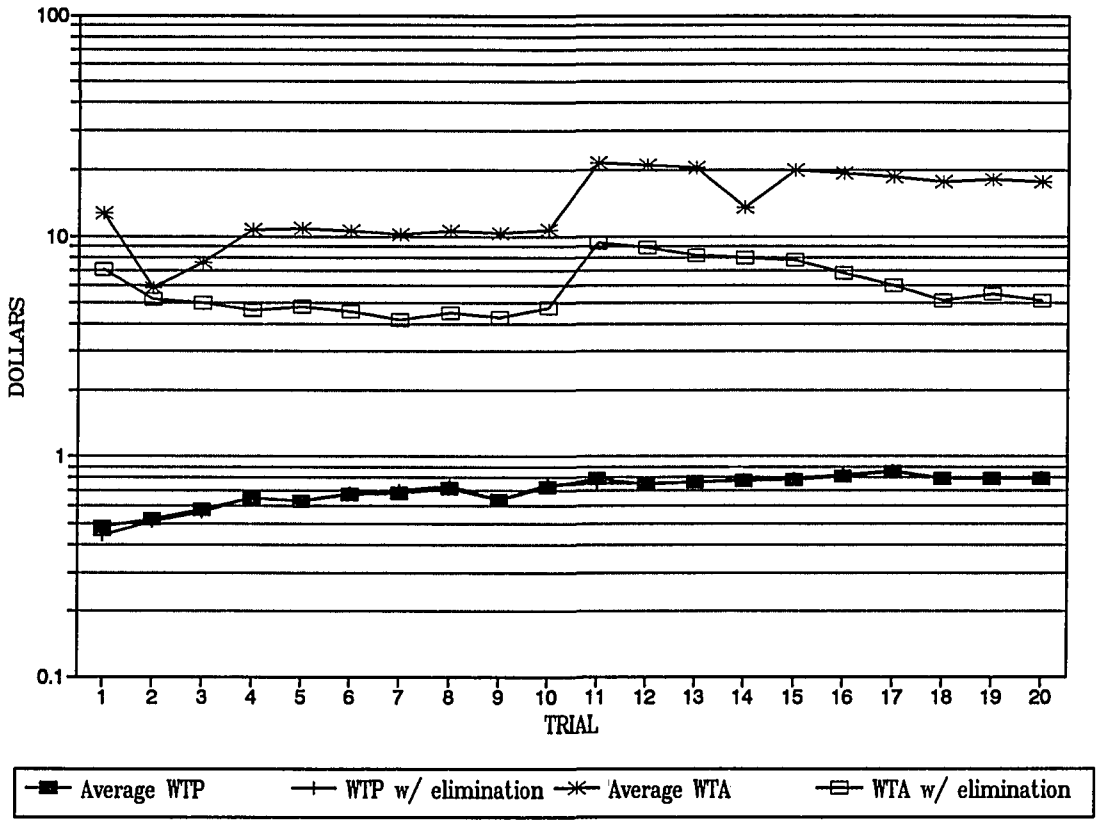


Figure 6. WTP and WTA comparison: *Trichinella spiralis*

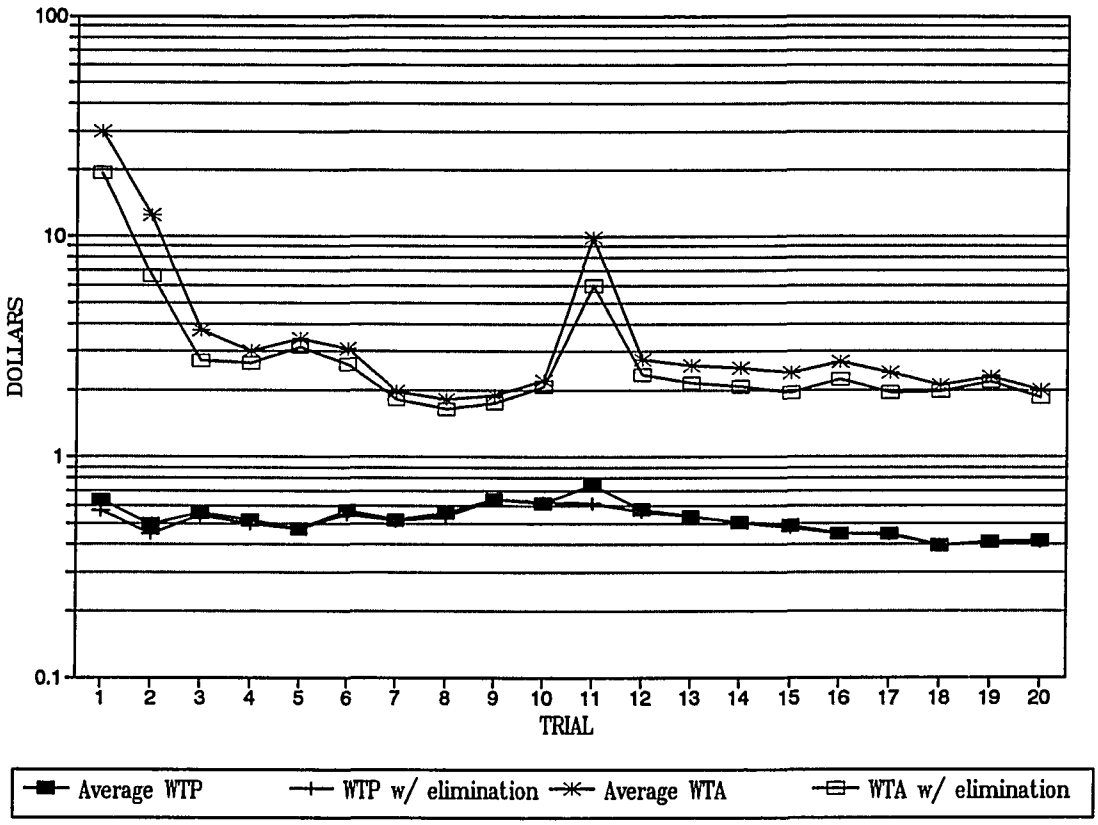


Figure 7. WTP and WTA comparison: *Clostridium perfringens*

APPENDIX

EXPERIMENTAL INSTRUCTIONS

#____

GENERAL INSTRUCTIONS

You are about to participate in an experiment about decision making. Please follow the instructions carefully. The United States Department of Agriculture has provided funds for this research.

SPECIFIC INSTRUCTIONS

In this experiment, you will be asked to decide how much you would be willing to pay for safer food. The experiment has two stages.

Your starting income will be $3 in stage 1. Your income will be $15 for stage 2. Your take-home income will consist of your initial income ($3 + $15) minus the value of goods purchased.

You will submit your bidding price on a recording card. Note only one of the trials in stage 1 will be binding and only one of the twenty trials in stage 2 will be binding. A number will be randomly selected to identify these binding trials.

You cannot reveal your bids to any other participant. Any communication between bidders during a trial will result in an automatic penalty of $3.

ABOUT YOU

1. Your sex : _____ Male _____ Female

2. Your age : ____ 19 or under
____ 20 - 24
____ 25 - 29
____ 30 - 34
____ 35 - 39
____ 40 - 44
____ 45 - 49
____ 50 or over

3. How many individuals live in your household, including yourself? ____

   If you have children, how old are they? _ _ _ _

4. Do you eat red meat? ___ Yes ___ No

   Do you eat poultry? ___ Yes ___ No

   Do you eat fish? ___ Yes ___ No

5. How often do you eat red meat, poultry, fish?

   Number of times you eat red meat per week? ____

   Number of times you eat poultry per week? ____

   Number of times you eat fish per week? ____

6. Do you eat chicken sandwiches? ____ Yes ____ No

7. Have you ever had food poisoning?

   ____ Yes ____ No ____ Don't know

8. If you became sick with a food-borne disease, how much money would you lose per day in addition to medical costs (i.e., lost wages)?

   _____ dollars per day

   _____ If you have sick leave benefits still indicate what your wage rate on this line.

CONSENT FORM

#____

You are about to participate in an experiment in willingness-to-pay for food safety. The purpose is to gain insight into what you are willing to pay for the guarantee that a food product will be safe.

We need your signed consent if you are to act as a subject. Your participation in the experiment is completely voluntary and you may withdraw from the experiment at any time without prejudice to you. Results from the experiment will be strictly confidential. Any name associated with the experiment will be deleted upon completion of the experiment.

If you consent to participate in the experiment, please sign the consent form below.

I have read the consent form statement and agree to act as subject in the experiment, with the understanding that I can withdraw from the experiment at any time without prejudice to me.

_____ / / _____

Signature Date

STAGE 1 #____

Step 1 : You <u>own</u> the candy free in front of you. Your initial income is $3.

Step 2 : Let's say you are willing to pay $X for the piece of candy and $Y for a candy bar. The <u>difference</u> ($Y - $X) is what you are willing to pay to upgrade your piece of candy into a candy bar. Please indicate your willingness to pay to trade the piece of candy for a candy bar. Do <u>not</u> state what you would pay for an entire candy bar. Only state the <u>difference</u> ($Y - $X) you are willing to pay.

Step 3 : Please write your bid (difference) for the <u>one</u> candy bar on the recording card. The monitor will announce the highest bidder and display the price of the candy bar (<u>second-highest bidding price</u>) on the blackboard.

Note : For example, if the highest bid was $$\alpha$$ and the second-highest bid was $$\beta$$, the highest bidder would receive the candy bar and must pay $$\beta$$.

Step 4 : There will be five trials.

Step 5 : Only one trial will be binding. After the five trials, a number will be randomly selected to determine which trial is binding. The highest bidder of that trial will exchange the piece of candy for the candy bar and must pay the displayed price (i.e., <u>the second-highest bid</u>).

Note : In the event that there is a tie for the highest bid, those participants will be asked to bid again.

Questions

Please answer the following questions, which are designed to help you understand stage 1. Do not hesitate to ask the researchers if you have questions.

1. Suppose that person A is the highest bidder in the first trial, person B is the highest bidder in third trial, and person C is the highest bidder in fifth trial. If, after five trials are finished, we randomly select the third trial, then who will purchase the candy bar?

   _____

2. If your $α bid is the highest in the third trial, and the second-highest bid is $ß, what price will you pay for the candy bar?

   $_____

3. If your bid is not the highest in the third trial, which is randomly selected, how much should you pay for the piece of candy?

   $_____

STAGE 2 #____

Step 1 : There are two types of food. The features of each are described below.

Test Product

This food has a typical chance of being contaminated with the food-borne pathogen Salmonella; i.e., it is purchased from a local source.

Stringently Screened

This food has been subjected to stringent screening for Salmonella. There is a 1 in 100,000,000 chance of getting salmonellosis from consuming this food.

Step 2 : You own a test product sandwich free in front of you. Everyone has the same sandwich. You also have initial income, $15.

Step 3 : Let's say you willing to pay $X for the test product sandwich and $Y for the stringently screened sandwich. The difference ($Y - $X) is what you are willing to pay to reduce the risk of illness from the food-borne pathogens.

Please indicate your willingness to pay to reduce the risk of illness. Do not state what you would pay for the entire stringently screened sandwich. Only state the difference ($Y - $X) you are willing to pay.

The highest bidder will upgrade his or her test product sandwich for the stringently screened sandwich. He or she will pay the second-highest bidder's price.

Step 4 : There will be twenty trials.

Step 5 : After all twenty trials are complete, we will randomly select one binding trial to determine who buys the stringently screened food.

Note : The sandwich has to be eaten to leave with the take-home income.

Questions

Please answer the following questions, which are designed to help you understand stage 2. Do not hesitate to ask the researchers if you have questions.

1. There are twenty bidding trials. If person A is the highest bidder in the first trial, person B is the highest bidder in the eighteenth trial, and the eighteenth trial is selected, then who will receive the stringently screened food? _____

2. If your $\$\alpha$ bid is the highest in the eighteenth trial, and the second highest bid is $\$\beta$, what price will you pay for the stringently screened food? $_____

NOTE : Please answer the questions below.

1. What do you think is the chance of becoming ill from Salmonella, given that you eat an average amount of typical food products in the United States over one year?

   Answer: _____ chance out of 1 million people

2. What do you think are the important sources of the food-borne pathogen, Salmonella, in the United States?

   Please list the type of food items.

   _____ _____ _____

Information for Trials 11-20 # ____

Test Product

If you eat this food, there is a 1 in 137,000 chance that you will become ill from Salmonella.

Stringently Screened

This food has been subjected to stringent screening for Salmonella. There is a 1 in 100,000,000 chance of getting Salmonellosis from consuming this food.

Description of Salmonellosis :

Symptoms are those of a mild "flu-like" intestinal disease of short duration with abdominal pains, nausea, vomiting, and diarrhea. The actual individual chance of infection of salmonellosis is 1 in 125 annually. Of those individuals who get sick, 1 individual out of 1,000 will die annually. The average cost for medical expenses and productivity losses from a mild case of salmonellosis is $220.

AGREEMENT OF UNDERSTANDING FORM

#____

The risks you took in eating this food are identical to those you take when eating meals you prepare at home or purchase when eating out.

Please sign below to indicate that you have read and understood the above announcement.

_____ / / _____

Signature Date

SECTION III.

CONSUMERS WILLINGNESS TO PAY FOR SAFER PORK PRODUCTS

INTRODUCTION

Approximately 26 percent of the average U.S. consumer's weekly food-at-home expenditure is for meat, poultry, fish, and eggs. Beef accounts for 33 percent, and pork, the second-ranking item, accounts for 19 percent of the weekly meat, poultry, fish, and egg expenditure (USDA 1991). Average annual pork consumption was 48.4 pounds in 1989, which represents one-fourth of total U.S. meat, poultry, and fish consumption (USDA 1991).

During the 1980s, per capita beef consumption gradually decreased and pork consumption was stable. Today's consumers are demanding leaner meat products, and the pork industry's effort to provide leaner pork products has helped maintain consumption levels. Additionally, programs for regulating the use of antibiotics in hog feeds and the use of nitrites in processing pork have aided in enhancing pork quality.

Two examples of food-borne illnesses transferred through pork products are salmonellosis and trichinosis. Contamination of pork products leads to human illness, economic loss to society, and perceived quality problems by consumers. Programs for inspection and reduction of *Trichinella spiralis* has improved the safety of pork products. Annually, approximately two million cases of Salmonellosis (Bennett et al. 1987) and 70 percent of the trichinosis cases are associated with eating inadequately cooked or treated pork products (CDC 1990). This pattern has led consumers to overcook pork, which has significantly reduced palatability and deterred demand.

An active policy to improve pork safety would permit consumption of a medium-rare pork chop, a product likely preferred by consumers (Hayenga et al. 1985). Consumer demand for pork products can be enhanced by providing products with improved quality and safety.

Food-borne illnesses, such as salmonellosis and trichinosis, cause large social and economic losses annually. These costs include medical treatment costs, productivity loss, pain and suffering of affected individuals, food industry losses, and losses within the public health sector (Roberts and van Ravenswaay 1989). Estimated losses are generally based on these direct individual losses (Roberts 1989) and likely represent an underestimation of the true economic costs. Morbidity costs such as consumers' willingness to pay (WTP) to reduce their chance of becoming sick from a food-borne sickness have been excluded.

The primary focus of this study is to evaluate consumers' WTP for safer food and reduced morbidity. The value of consumers' WTP to avoid morbidity or mortality from food-borne illness caused by pathogenic microorganisms such as *Salmonella* and *Trichinella spiralis* are estimated. Additionally, consumer perceptions of the level of food safety are evaluated. Consumer responses or their WTP for improved food safety are compared using two approaches. The first is the naive response based on prior subjective information. The second is the consumer's WTP after being provided of information on the actual probability of food-related sickness.

Information on consumers' WTP for food safety are obtained through a nonhypothetical laboratory experimental approach. Participants were provided the

opportunity to eat an ordinary meat product (maybe contaminated) free of charge or they could bid by auction for a product that was guaranteed to be free of *Salmonella* or *Trichinella spiralis*. A Vickrey second-price sealed-bid auction was used to elicit consumers' WTP for reduced pathogen risks. The Vickrey auction has been shown to accurately reveal preferences for other goods (see Coursey 1987).

EXPERIMENTAL DESIGN

The consumers' WTP was obtained through observing the preference or the value of the unpriced goods within Vickrey's (1961) second-price sealed-bid auction setting. As long as the individual prefers more money to less, the laboratory experiment can elicit the consumer values of the unpriced goods. There are two stages in the experiment. Stage 1 is an exercise to familiarize the subjects with the auction procedure by using Vickrey's second-price sealed-bid auction for a highly familiar food item for which the subjects have some idea of value. In Stage 2, $15 was provided as income to each participant. Two food-borne pathogens were considered in two separate experimental sessions. Each participant was involved with one food-borne pathogen, *Salmonella* or *Trichinella spiralis*. At the beginning of Stage 2, two types of food items were shown to the subjects and a description was provided for each item. One item was the test product, purchased from a local source with a typical chance of being contaminated with *Salmonella* or *Trichinella spiralis*. This product was provided free to every participant. The other food product was stringently screened for *Salmonella* or *Trichinella spiralis* and had a low chance (one in 100 million) of causing salmonellosis or trichinosis.

Participants were asked the maximum they were willing to pay to upgrade the test product for the food product that had been stringently screened for pathogens. There were twenty trials in each experiment. For each trial, the participants' recording cards were collected by the monitor, and the monitor announced the

highest bidder and displayed the price of WTP for the screened food (second-highest bidding price) as public information on the blackboard. Repeating the auction over twenty trials provided a learning period for the participants, allowing them to converge to their true WTP value. To control for possible wealth effects, subjects were made fully aware that only one of the twenty trials was binding. The binding trial was randomly selected by a Monte Carlo number generator after completion of all twenty trials.

The first ten "naive" trials were conducted with the participants making bids based on their prior risk perceptions of salmonellosis (or trichinosis). After the tenth trial, the monitor provided additional information about the actual chance of contracting salmonellosis (trichinosis). There is a one in 137,000 chance of infection of *Salmonella* (one in 2,628,000 for *Trichinella spiralis*) from one-time consumption of the typical product. The actual individual chance of infection annually from *Salmonella* is one in 125 (one in 2,400 for *Trichineila spiralis*), and of those who contract salmonellosis, one in 1,000 (for trichinosis, one in 100) will die annually (Bennett et al. 1987). The symptoms (Acha and Szyfres 1980) and average medical cost ($220) of a mild case of salmonellosis ($2,485 for trichinosis) (Roberts 1989) were also provided. Participants then bid in ten informed trials to complete the experiment. After twenty trials, a computer randomly selected one binding trial to decide who purchased the screened food. The highest bidder paid the displayed second-highest bidding price and then ate the screened food. The highest bidder's take-home income was the $15 minus the price paid for the screened food. The other bidders ate the test product and had a take-home income of $15. The

participants had to eat the food item to leave the experiment with the take-home income.

Fifteen students at Iowa State University (ISU) participated in each experiment. Each experiment had a different set of students. Experiments were conducted in the ISU meat testing laboratory with modern kitchen facilities. The ISU lab conducts food tasting experiments on a regular basis and is actively involved in all aspects of meat processing and handling, thereby providing a unique setting for our experiment.

RESULTS AND DISCUSSIONS

Figure 1 provides the results for the experiments. The first trial, an inexperienced one-shot bid, was analogous to the survey valuation method. The average WTP in the first trial was 61 cents for the *Salmonella* experiment and 48 cents for the *Trichinella spiralis* experiment. The average WTP of trials 7 through 10 with subjects' naive information was 44 cents for the *Salmonella* experiment, and 69 cents for the *Trichinella spiralis* experiment, which was 17 cents lower and 21 cents higher than the average inexperienced first bid, respectively. Subjects in the *Salmonella* experiment had a lower WTP bid with repeated market-like exposure; however, in the *Trichinella spiralis* experiment, the subjects' naive bid was increased by 44 percent with market exposure.

Subjects increased their WTP value at trial 11 in both experiments. Their prior subjective probability of becoming ill from eating a year's supply of the typical food product was one in 212,000 for *Salmonella* and one in 6,186,440 for *Trichinella spiralis,* both of which were lower than the actual probability. For trials 17 through 20, the mean WTP was 55 cents for *Salmonella*, which was 24 percent greater than the average WTP for trials 7 through 10. For *Trichinella spiralis*, the informed bid was 81 cents, which was 16 percent greater than the average WTP of trials 7 through 10 (69 cents).

Table 1 compares the mean of trials 7 through 10 with the mean of trials 17 through 20. The t-test and signed-rank test indicate that the WTP differences

between naive and experienced bids for *Salmonella* and *Trichinella spiralis* were statistically significant at the 1 percent and 10 percent significance level, respectively. Full information and repeated exposure to the auction market had an impact on average WTP values.

CONCLUSION

Overall, the results indicate that the subjects were willing to pay more for the safer food product than for the typical food product. In the first trial, which is equivalent to a field survey method, subjects bid higher WTP values than the bid with repeated market exposure for *Salmonella* and less for *Trichinella spiralis*. With naive information, bids converged to a lower WTP value for *Salmonella* and a higher value for *Trichinella spiralis*. Subjects evaluated their prior subjective probability of illness as lower than the actual level. Therefore, with full information, their bids increased from the level of their naive bid.

This study provides additional information for approximating the full economic costs of food-borne illness and expands the capability of providing a cost-benefit analysis of food safety policies. The WTP approach opens the avenue for more accurately estimating total economic costs of food-borne illness. Potential benefits of alternative methods for reducing food-borne infectious disease, such as irradiation treatment for raw pork, can be better estimated.

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TABLE AND FIGURE

Table 1. Summary statistics of experiments

Pathogen (Probability of Illness)	Mean willingness to pay		
	Inexperienced (1st trial)	Naive (7th-10th trials)	Informed (17th-20th trials)
Salmonella (1/137,000)	0.6120 (0.5331)[a]	0.4448 (0.2278)	0.5523 (0.2534)
Trichinella spiralis (1/2,628,000)	0.4808 (0.4161)	0.6942 (0.4611)	0.8069 (0.5542)
		H_0: $WTP^{17-20} = WTP^{7-10}$ H_1: $WTP^{17-20} > WTP^{7-10}$	
	Mean difference[b]	t-test	Signed-rank test
Salmonella (1/137,000)	0.1075 (0.1008)	4.1286[c]	39[c]
Trichinella spiralis (1/2,628,000)	0.1127 (0.2552)	1.5920[d]	19[d]

Note: The sample size of *Salmonella* experiment was n = 15; sample size of *Trichinella spiralis* experiment was n = 13.

[a]Standard deviations are in parentheses.

[b]Represents the mean difference between average WTP in trials 17 through 20 and average WTP in trials 7 through 10.

[c]Denotes rejection of H_0 at the 1 percent significance level for both t-test and Wilcoxon signed-rank test.

[d]Denotes rejection of H_0 at the 10 percent significance level for both t-test and Wilcoxon signed-rank test.

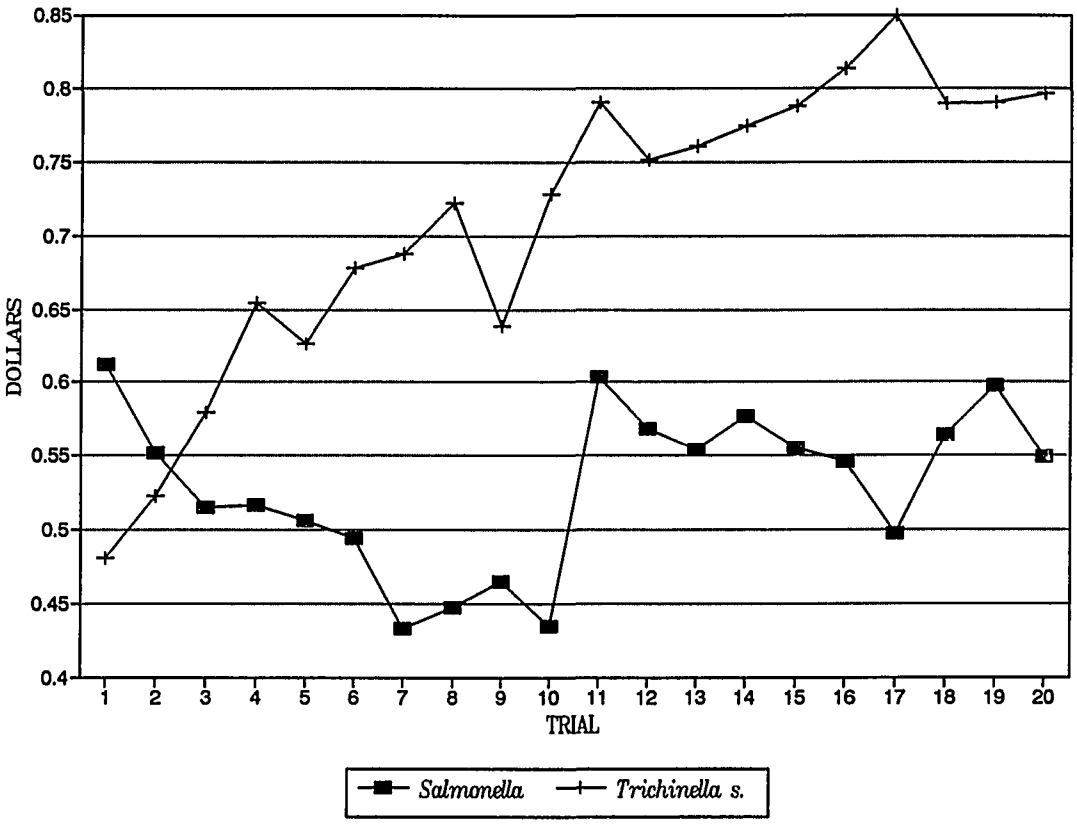

Figure 1. Comparison of average WTP: *Salmonella* and *Trichinella spiralis*

GENERAL SUMMARY AND DISCUSSION

Food safety issues are analyzed in terms of the economic costs of food-borne illness. A willingness to pay (WTP) value of the safer food and willingness to accept (WTA) value of bearing additional food-borne risks are estimated. A non-hypothetical laboratory experimental design was developed for estimating the WTP and WTA measures of safer food using the Vickrey's second-price sealed-bid auction mechanism.

Previous studies have estimated the economic cost of food-borne illness based only on direct individual costs, such as productivity losses, and hospitalization costs. These measures underestimate the true economic costs. This study included the cost of morbidity which was represented by WTP value of not having a food-borne illness and the WTA value of the compensation required for bearing the food-borne risks. These estimates represent a comprehensive economic costs of food-borne illness and are close to the upper bound of the measures among the previous cost estimates.

This research supports several conclusions about consumers behavior. First, full information of the food-borne illness and repeated market-like auction mechanism has an impact on participants' average WTP and WTA bids. Second, there exists a disparity between the nonmarket good (health) and wealth with given positive income elasticity and small elasticity of substitution. Third, the results of the pathogen specific experiment could not be compared in terms of the full economic costs (WTP) of the specific pathogens. The consumers responded to the presence of the food-

borne risks in general rather than the risk level of the specific food-borne pathogens. Fourth, this research does show that the WTP value for the safer food is surprisingly large--this may explain the current emphasis on food safety in the United States.

This study provides additional information on the full economic costs of food-borne illness and expands the capability of providing cost-benefits analysis of food safety policies. The nonhypothetical laboratory experiment method used in this study is shown to be a useful method to address the food safety issues.

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