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Abstract

This paper examines the effect of ambiguity about health risks on consumers' willingness to pay for reduced pesticide residues in food. A theory of consumer choice in a hypothetical market for regular and reduced-residue apples is developed using Segal's ambiguity version of Quiggin's rank-dependent expected utility model. Survey data on consumer purchase intentions in this market and perceptions of risk and ambiguity are used to estimate demand. Willingness to pay for reduced pesticide residues on apples is calculated using Hellerstein's measure of expected consumer surplus. The effect of changing perceptions of risk and ambiguity is calculated via simulation. Implications for policy and future research are developed.

Introduction

The U.S. Government and the food industry face difficult decisions about how much of their limited resources to allocate to reducing pesticide residues in food. Current U.S. law prohibits the presence in food of residues of pesticides that may cause cancer, no matter how small the risk. Many scientists argue, however, that pesticide residues in food are so minuscule that they pose no real health risk. Several bills to change the law have been proposed, but legislators hesitate to vote for a law that public interest groups claim will weaken food-safety regulation, especially given public concern about the dangers of pesticide residue in food.

To design policies that effectively address consumers' concerns, policy makers should understand how consumers make choices in the face of potential risks from pesticide residues. Several studies have estimated the effect of consumers' risk perceptions on willingness to pay (WTP) for reduced pesticide residues (Hammitt, van Ravenswaay and Hoehn, Eom). One surprising finding of these studies is that risk perceptions appear to play only a small role in determining consumers' WTP for reduced pesticide residues in food. The difference in WTP between consumers who perceive large risks and those who perceive very small risks is much smaller than expected given empirical estimates of WTP for reduced mortality and morbidity risks (e.g., Fisher et al., Viscusi). If this finding is correct, then there must be additional factors that help determine consumers' preferences for and benefits from restricting pesticide residues in food. This possibility suggests that food-safety policies other than reducing the risks from pesticide residues may be important. If the finding is not correct, then either current methods of measuring consumer risk perception and WTP for reduced pesticide residues are inadequate, or empirical estimates of WTP for reduced mortality and morbidity risks are invalid. This possibility highlights the need for research regarding appropriate methods for obtaining risk perceptions and WTP estimates.

This paper explores the possibility that ambiguity about health risks is a factor (in addition to risk perceptions) that affects consumer WTP for reduced pesticide residues in food. Ambiguity is defined as uncertainty about the probability of an outcome.[1] It results because of the inherent difficulty in assessing the levels and hazards of pesticide residues in food. Since

[1] In this paper, ambiguity refers to only the uncertainty about the probability of an outcome; it assumes there is no uncertainty about the **types** of potential outcomes.

pesticide residues are undetectable in food and since food is generally not labeled for its residue levels, consumers do not know the exact levels of pesticide residues they ingest. Furthermore, consumers receive conflicting information about the potential health effects of pesticide residues, and they may not trust that policies regarding allowable levels of residues are adequate or are being strictly enforced (van Ravenswaay 1995). Focus group research revealed that consumers are often uncertain about the possibility of adverse health outcomes resulting from the ingestion of pesticide residues on food (van Ravenswaay and Hoehn, Buzby et al.). Current scientific controversy over the validity of pesticide risk assessments compounds consumer ambiguity about risk assessments.

If ambiguity about risks is an important determinant of consumers' WTP, policies to reduce ambiguity may have value. Consumers may value knowing the standards for pesticide residues in food, for example, and what those standards mean. Similarly, information about what is being done to enforce the standards may be beneficial to consumers. This information helps consumers better assess the risks they face from pesticide residues without necessarily changing the actual risk they face. Furthermore, a better understanding of the role of ambiguity in consumer choice may give us insight as to why people are WTP when risk and risk reductions are perceived to be small. It may also have implications for interpretation of existing estimates of WTP for reduced mortality and morbidity which assume no ambiguity.

There are two public policies that lead to reduced pesticide residues on food: the Government can establish tougher standards for the amount of residues allowable in food and/or it can allocate more resources to the enforcement of current standards. Furthermore, foods that meet tougher standards and/or that are subject to tougher enforcement can be labeled accordingly. The goal of this research is to examine the influence of consumer ambiguity about the risk on WTP for this type of labeling on food.

Consumers pay for tougher enforcement and standards through higher food prices. Consequently, hypotheses about willingness to pay should be based on market choices. Since well-developed markets for foods that are labeled for their level of pesticide residues do not currently exist, this study used the results of a contingent valuation survey to estimate consumers' WTP for these foods. The survey asked Michigan residents about their apple-purchasing behavior in both actual and hypothetical shopping situations. It also solicited their perceptions of the current risks from pesticide residues in food and their "sureness" about those risks. We use these measures of "sureness" as proxies for a measure of ambiguity.

Fresh apples were chosen for study because of the prevalence of apples in the U.S. food basket; approximately 90% of all U.S. households purchase apples. Furthermore, the price of apples is likely to be affected if pesticide use is restricted.

Although the ultimate goal of this type of research is to estimate the benefits associated with certifying all types of foods for their pesticide residue levels, it is difficult to develop a valid, reliable, and practical way to do this. Respondents are unable to accurately predict how their total food purchases would change if, for example, prices of labeled foods were some percent over the prices of regular foods. A survey involving many types of foods would be extremely lengthy and would increase the problems associated with nonresponse. The survey used in this research explores the decisions about only one food (apples) in order to increase the validity of the results and reliability of the responses. It does this by developing a more detailed and realistic scenario for consumers to evaluate than is possible with more than one food.

Theoretical Framework

Most models of choice about health risks (e.g., Cropper and Freeman, Eom, Jones-Lee, Viscusi) assume that people assign numerical probabilities to all possible health outcomes with total certainty. In reality, people may be uncertain about the probabilities of the health outcomes associated with certain choices. In the case of choices about foods that may contain pesticide residues, for example, consumers may not be able to accurately assess the health risks they face. Foster and Just model this uncertainty using the variance of the probability distribution over outcomes. Their approach assumes people are certain about the mean and the variance of the probability distribution over health outcomes. In this paper, we explore the case where consumers are uncertain not only about which health outcome will occur, but they are also uncertain about the specification of the probability distribution over outcomes. That is, the probability of any particular health outcome resulting is itself a random variable. We call this a situation of ambiguity to distinguish it from the situation of risk.

Segal (1987) develops the theoretical implications of ambiguity by extending Quiggin's (1982) Rank-Dependent Expected Utility Model (RDEU). The RDEU is an extension of the simple probability weighting model (Eihnhorn and Hogarth 1985, 1986; Hogarth and Kunreuther 1989; Fellner 1961; Viscusi and O'Conner 1984; Viscusi and Magat 1992; Hazen 1987; and Kahneman and Tversky 1979) to multiple outcomes. It is a generalized utility model that maintains several of the features of the expected utility model (transitivity, completeness, continuity, and first-order stochastic dominance). The RDEU uses non-linear decision weights instead of objective probabilities of outcomes to weight the utility of outcomes. Segal constructs the decision weights to reflect ambiguity about the probability distribution over outcomes. In his model, choices involving ambiguous probabilities are initially conceptualized as a two-stage lottery where the first-stage lottery determines the probability of outcomes and the second-stage lottery determines the outcome, using the result of the first-stage lottery as the relevant probability. A crucial assumption of the model is that decision makers evaluate the two-stage lottery according to the Compound Independence Axiom (CIA) rather than the Reduction of Compound Lotteries Axiom (RCLA). Under CIA, the two-stage lottery is transformed into a one-stage lottery using probability "certainty equivalents," i.e., the certain probability of an outcome one would accept rather than not know what the probabilities of outcomes were. Under RCLA, ambiguity does not affect choice because the two-stage lottery reduces to a one-stage lottery (i.e., the probability of a probability is reduced to a single probability).

In the RDEU, the decision weight of the probability (π_k) of outcome x_k depends on the probabilities (π_s $\forall$ $s=1\ldots n$, $s\neq k$) of the other possible outcomes (x_s $\forall$ $s=1\ldots n$, $s\neq k$) and the rank, or desirability, of outcome x_k relative to all other x_s. If the lottery X offers n outcomes (i.e., outcomes x_s where $s=1\ldots n$), and the outcomes can be ranked in order of preference ($x_1 < \ldots x_s < \ldots x_n$), the RDEU takes the following form:

$$RDEU = V(X) = \sum_{s=1}^{n} h_s(\pi)u(x_s) \qquad (1)$$

where:

$$h_s(\pi) = f(\sum_{j=1}^{s} \pi_j) - f(\sum_{j=1}^{s-1} \pi_j) \qquad (2)$$

and π is the vector of probabilities ($\pi_1, \pi_2, \ldots \pi_n$) of other outcomes, the function f "transforms" the probability (which always lies between 0 and 1) such that the transformed probability remains between 0 and 1 (i.e., $f[0,1] \rightarrow [0,1]$). It is assumed that $f(0)=0$ and $f(1)=1$. The decision maker chooses the act X that has the highest RDEU.

For simplicity, assume a decision maker faces a lottery with two possible outcomes: x with probability π, and 0 with probability $1-\pi$. This is written as:

$$X = (x, \pi ; 0, 1-\pi) \tag{3}$$

Now assume that π is itself a random variable, $\tilde{\pi}^g$, where $g=1...m$ (m is the total number of possible probabilities of a given outcome). The probability that the actual probability of outcome x is π^g is q^g. That is, the probability that the lottery one will face is actually $(x, \pi^g; 0, 1-\pi^g)$ is q^g.

Segal assumes that instead of using the RCLA, decision makers adhere to the Compound Independence Axiom (CIA): Let A be a two-stage lottery: $A=(X_1,q^1;...X_m,q^m)$ and define $CE(X_i)$ by $(CE(X_i),1) \sim X_i$.[2] This notation says the decision maker is indifferent between getting the certainty equivalent of the X_i lottery ($CE(X_i)$) and facing the lottery X_i. The decision maker is then also indifferent between facing lottery A and facing the lottery $((CE(X_1),1),q^1;...(CE(X_m),1),q^m)$. For example, a decision maker may be indifferent between a situation in which the probability of experiencing an adverse health outcome because of pesticide residues is somewhere between 0.1 and 0.00001, with an average probability of 0.050005, and knowing for certain that the probability is 0.07.

If there is a "certainty equivalent" for each first-stage lottery above then:

Solving equation 4 for $CE(X_i)$ yields:

---

[2] The lottery $(CE(X_i),1)$ is a degenerate lottery in which the decision maker receives $CE(X_i)$ with certainty.

$$u[CE(X_i)] = [V(X_i)] \tag{4}$$

$$CE(X_i) = u^{-1}[V(X_i)] \tag{5}$$

Substituting $u^{-1}[V(X_i)]$ into the RDEU in which there are only two outcomes (x and 0) to the lottery X_i and assuming $u(0)=0$ yields:[3]

$$\begin{aligned} RDEUWA = V(X) &= u(x,M)\,\bar{f}(\pi^1) \\ &+ u(x,M)\sum_{i=2}^{m}[\bar{f}(\pi^i) - \bar{f}(\pi^{i-1})]\bar{f}(\sum_{g=i}^{m} q^g) \end{aligned} \tag{6}$$

where:

RDEUWA	=	Rank-Dependent Expected Utility with Ambiguity
u	=	utility function
x	=	outcome
M	=	income
π^i	=	the i[th] possible probability of outcome x
q^g	=	the probability that π^g is the actual probability of outcome x
$\bar{f}$	=	the probability transformation function
m	=	the number of possible values that γ^i can take

Each π^i can alternatively be written as a deviation from the mean probability of an outcome, π (Segal 1987):

[3] The RDEU uses the transformation function, f, when π is the probability of a "good" outcome. The transformation function when π is the probability of a "bad" outcome is $\bar{f}$ which is equal to $1-f(1-\pi)$ (Segal 1987). Since survey respondents were asked their perception of the probability of an adverse health effect from pesticide residues in food (a "bad" outcome) we use the transformation function $\bar{f}$.

$$\pi^i = \pi + \gamma^i \epsilon \tag{7}$$

where:

π^i	=	the i^{th} probability of outcome x
π	=	the mean probability of outcome x
γ^i	=	a measure of the distance between π and π^i. The term γ^i varies with the possible probabilities. It does **not** vary by person.
ϵ	=	a measure of the distance between π and π^i. The term ϵ varies by person, but does **not** vary with the individual probabilities.

Together, γ^i and ϵ determine the spread of $f(\pi)$, referred to below as the second order probability distribution (SOP). The term ϵ varies by individual, while the term γ^i varies with the possible probabilities. To conform to the laws of probability, the following restrictions must also hold:

1) $0 < \gamma^i \epsilon < 1$

2) $0 \leq \pi - \gamma^i \epsilon \leq 1$

Since only π and ϵ vary by person, ϵ is as a measure of the perceived ambiguity around π. The higher ϵ, the higher the perceived ambiguity.

The RDEU with the probabilities written in terms of deviations from the mean is written as:

$$\begin{aligned} RDEUWA &= u(x,M)\bar{f}(\pi + \gamma^1\epsilon) \\ &+ u(x,M)\sum_{i=2}^{m}[\bar{f}(\pi + \gamma^i\epsilon) - \bar{f}(\pi + \gamma^{i-1}\epsilon)]\bar{f}(\sum_{g=i}^{m} q^g) \end{aligned} \tag{8}$$

The two-stage lottery is now represented by a one-stage lottery by using the Compound Independence Axiom (certainty equivalents). The resulting objective function then depends not only on the mean probability of the outcome, but also on the perceived ambiguity about that probability. The objective function also depends on individual preferences toward ambiguity, i.e., on the shape of the transformation function, $\bar{f}$. If $\bar{f}$ is linear, the individual is ambiguity neutral (he/she doesn't care if the probabilities are certain or uncertain). In this case, the objective function reduces to the RDEU. If $\bar{f}$ is concave (convex), the individual is ambiguity averse (loving). When deciding between alternative "ambiguous" acts or lotteries, the decision maker maximizes RDEUWA.

Segal (1987) shows using the RDEUWA that a less ambiguous lottery has a higher value (in terms of the RDEUWA) than a more ambiguous lottery provided the following assumptions about the probability transformation function hold:

1) the transformation function, $\bar{f}$, is concave;

2) $\frac{\pi \bar{f}'(\pi)}{\bar{f}(\pi)} \leq 0$

3) $\frac{\pi f'(\pi)}{f(\pi)} \geq 0$

4) $\frac{\bar{f}''}{\bar{f}'} \geq 0$

He also shows that a non-ambiguous lottery has more value than an ambiguous one. This can be written as:

$$u^o = v(p_c, p_r, \pi^r, \epsilon^r, M) < v(p_c, p_r, \pi^r, \epsilon^c, M) = u^1 \tag{9}$$

where:

$\epsilon^c < \epsilon^r$.

If equation 9 holds, then there must be some positive amount of money (CV) that can be taken away from the consumer such that he/she is indifferent between the situation with higher ambiguity and income M, and lower ambiguity and income (M-CV), holding mean risk constant at π^r. That is, there is some positive amount, CV, that solves the following:

$$u^o = v(p_c, p_r, \pi^r, \epsilon^r, M) = v(p_c, p_r, \pi^r, \epsilon^c, M - CV) \tag{10}$$

The term CV is the Hicks compensating variation for a change in ambiguity from ϵ^r to ϵ^c.

If the consumer maximizes utility subject to a budget constraint, he/she can also be said to minimize expenditures subject to a given level of utility. In terms of the expenditure function, the CV can be written as follows:

$$CV = e(\pi^r, \epsilon^c, u^o) - e(\pi^r, \epsilon^r, u^o) > 0 \tag{11}$$

If Segal's assumptions hold, and the value of a less ambiguous lottery is higher than a more ambiguous one, then the willingness to pay for a marginal reduction in ambiguity from ϵ^r to ϵ^c must be positive. Consumers should thus be willing to pay some amount above what they would pay to get risk reduction only to get ambiguity reduction. Thus, we hypothesize:

$$-\left[\frac{\partial CV}{\partial \epsilon^c}\right]_{\epsilon^r} > 0 \qquad (12)$$

where $\left[\frac{\partial CV}{\partial \epsilon^c}\right]_{\epsilon^r}$ indicates that the expression is evaluated at ϵ^r. This can also be stated as the marginal value of a decrease in ambiguity is positive. This hypothesis can also be developed by using equation 10 to solve for $-(\partial CV/\partial \epsilon^c)$ (Wohl, 1994).

Application to Pesticide Residues in Apples

Suppose there were a market which offered regular apples at price p_r per pound and apples that have been tested and certified to meet certain standards for pesticide residues at price p_c per pound. The regular and the certified apples are identical except for their price and the certification about pesticide residues. Apples with different levels of residues are differentiated qualities of the same product; the choice between regular and certified apples is then a choice between two brands (regular and certified) of the same product (apples) that have a different quality dimension (different levels of pesticide residues) (Hanemann 1982). Each brand of the good is a separate commodity; the consumer selects the quality of the good implicitly by choosing a particular brand.

When a consumer buys regular apples, he/she perceives there to be some probability (π^r) of experiencing an adverse health outcome someday from the pesticide residues on those apples. When the consumer chooses the certified apple instead, the perceived probability of the same adverse health outcome is π^c. The difference between π^r and π^c is the amount of risk reduction the consumer perceives when switching to the certified apples.

The probability of an adverse health outcome in the case of uncertainty is a random variable; ϵ is a measure of the spread of the probability distribution around the mean probability (ϵ^r is the ambiguity associated with π^r, ϵ^c is the ambiguity associated with π^c). When the consumer buys the certified apple, he/she may be buying not only reduced risk, but may also be buying reduced ambiguity.

When deciding among "brands," the decision maker chooses the brand that yields the highest indirect expected utility. That is the decision maker chooses between:

$$RDEUWA = v_h(p_r,p_c,M)\bar{f}(\pi^r + \gamma^1\epsilon^r) + v_h(p_r,p_c,M)\sum_{i=2}^{m}[\bar{f}(\pi^r + \gamma^i\epsilon^r) - \bar{f}(\pi^r + \gamma^{i-1}\epsilon^r)]\bar{f}(\sum_{j=i}^{m} q^j) \tag{13}$$

for regular apples, and

$$RDEUWA = v_h(p_r,p_c,M)\bar{f}(\pi^c + \gamma^1\epsilon^c) + v_h(p_r,p_c,M)\sum_{i=2}^{m}[\bar{f}(\pi^c + \gamma^i\epsilon^c) - \bar{f}(\pi^c + \gamma^{i-1}\epsilon^c)]\bar{f}(\sum_{j=i}^{m} q^j) \tag{14}$$

for certified apples.

The compensating variation in the case of ambiguous risks is the amount of income the decision maker is willing to give up in exchange for a reduction in probability from π^r to π^c **and** a reduction in the ambiguity from ϵ^r to ϵ^c. That is, CV is the amount the decision maker is willing to pay for the certification. It satisfies the following equation:

In this research, the utility and indirect utility associated with no adverse health outcome are normalized to 0, i.e., $u_{nh}(\cdot)=0$ and $v_{nh}(\cdot)=0$. If the health effects from pesticide residues have a negative effect on utility, then utility and indirect utility in the state of the world in which one experiences an adverse health effect from pesticide residues are negative.

$$
\begin{aligned}
& v(p_r, p_c, M - CV)\bar{f}(\pi^c + \gamma^1\epsilon^c) \\
& + v(p_r, p_c, M - CV)\sum_{i=2}^{m}[\bar{f}(\pi^c + \gamma^i\epsilon^c) - \bar{f}(\pi^c + \gamma^{i-1}\epsilon^c)]\bar{f}(\sum_{j=i}^{m} q^j) \\
& = \qquad\qquad (15) \\
& v(p_r, p_c, M)\bar{f}(\pi^r + \gamma^1\epsilon^r) \\
& + v(p_r, p_c, M)\sum_{i=2}^{m}[\bar{f}(\pi^r + \gamma^i\epsilon^r) - \bar{f}(\pi^r + \gamma^{i-1}\epsilon^r)]\bar{f}(\sum_{j=1}^{m} q^j)
\end{aligned}
$$

We also assume that the parameter γ^i varies with the possible probabilities, but does **not** vary by individual. The scale of γ^i is such that whatever the scale of ϵ, $\gamma^i\epsilon$ will remain between 0 and 1. The term ϵ is not restricted to lie between any bounds.

The approach here also assumes that q^j, the probability that the j^{th} probability is the actual probability, is the same for all decision makers.

Figure 1 shows the SOP distribution of an adverse health outcome from pesticide residues for certified and regular apples for two consumers (consumer A and consumer B). The consumers perceive the same baseline risk (π^r) and the same amount of risk reduction (π^r-π^c) when switching from the regular apples to the certified apples. However, consumer A has a higher level of initial ambiguity than consumer B. The amount of risk reduction consumer A obtains when switching from regular to certified apples is uncertain because of the large variance in the SOP distribution. The risk faced after moving to the certified apple when risks are highly ambiguous may not be significantly different from the risk associated with the regular apple. The motivation to move to certified apples is then gone. The risk reduction for consumer B, on the other hand, is clear. Although the **mean** risk reduction is the same in both cases, the consumer with the high ambiguity should not be willing to pay as much for the certification as the low ambiguity consumer.

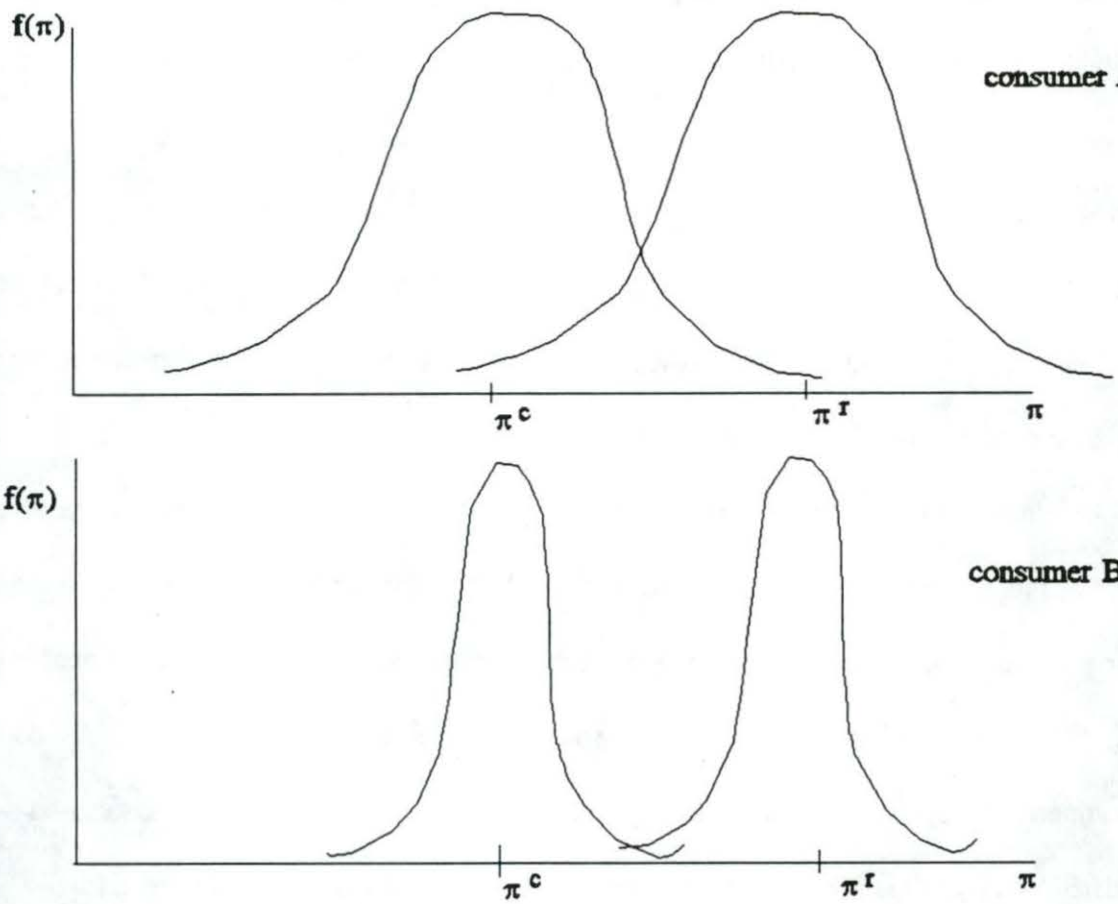

Figure 1: SOP for high initial ambiguity consumer (consumer A) and low initial ambiguity consumer (consumer B)

Thus, we hypothesize that WTP for certification **decreases** with ambiguity about risks on regular apples, holding ambiguity reduction, baseline risk, and risk reduction constant. In other words, we predict that consumers who perceive higher ambiguity from the regular apple should be willing to pay **less** for certification than those people who perceive lower ambiguity, *ceteris paribus*.

The CV for a change in the price of a good is equal to the area to the left of the Hicks-compensated demand curve between the initial and new prices (Freeman 1993). When a consumer switches from the regular apples to the certified apples he/she moves from a situation in which the price of the certified apples is prohibitively high (or, if the certified apples are not available, the price of certified apples is effectively infinite) to a situation in which the price of the certified apples is such that consumption of certified apples is positive. The CV for the certification is then the area to the left of the Hicks-compensated demand curve (h^c) between the price at which demand for certified apples is zero (the "choke" price) and the price at which the certified apples are offered. This is a measure of the surplus from the certified apples that is due strictly to the presence of the certification indicating the pesticide residue level.

When a consumer chooses the regular apple at a market price, he/she also receives some surplus; this surplus is due to the "appleness" of the regular apple that is worth something to the consumer above the market price. Since the regular and certified apples are identical except for their price and certification, when the consumer chooses the certified apple, he/she could have consumed the regular apple and still got the "appleness." The surplus associated with the certified apple is thus due **only** to the certification and not due to its "appleness."

The Survey and Data

The survey used in this research asked respondents to consider a hypothetical shopping scenario in which both regular and certified apples were available at stated prices. The survey did not ask people to directly state their willingness to pay for reduced pesticide residues or reduced risks since this is not a situation they are ever likely to face. Instead, it asked them about their apple-purchasing behavior under various scenarios. These are decisions people actually face when they buy apples; the responses are thus more likely to reflect real decision behavior.

When consumers choose between regular and certified apples, they must make two types of decision: which "brand" of apple to buy and how many apples to buy. Consequently, respondents were first asked if they would choose regular apples, certified apples, some of both, or no apples at all. They were then asked how many apples of that particular kind they would buy if they were planning to buy apples during a typical shopping occasion in the fall. The quantity purchased was converted to pounds.

Respondents were told the prices of both regular and certified apples. Each respondent received one of forty price combinations of regular and certified apples ranging from $0.49 to $1.19 for the regular apple and $0.49 to $1.59 for the certified apples. The prices of regular and certified apples were systematically varied to ensure price variation in the data. Respondents were told that all apples would look the same as those they usually buy.

The estimation of the surplus associated with the purchase of certified apples is based on specific prices for both regular and certified apples that are the same for all consumers. The price of the regular apple is the average retail price (per pound) of red delicious apples in Michigan in June/July, 1992 (the time period of the survey) of $0.98 per pound (United States Department of Agriculture 1993).

In order to estimate the cost per pound of certifying apples to have been produced without pesticides (or to meet federal standards for pesticide residues) this study used cost data from Nutriclean, a private organization located in California that certifies produce for pesticide levels. This calculation produced an estimate of $0.06 per pound. The price of the certified apples was thus $1.04 ($0.06 higher than the regular apple price).

Measuring Risk and Ambiguity Perceptions

Respondents perception of the risk associated with regular apples (π_r) was measured both qualitatively and quantitatively. Respondents were asked to suppose there were a million people from a household like theirs who did nothing to reduce or avoid pesticide residues in food (e.g., no washing, purchasing of organic, etc.). They were then asked what they thought the chances were that one of those million people would have a health problem someday because of pesticide residues in food. The qualitative response categories were: certain to happen, very likely, somewhat likely, somewhat unlikely, very unlikely, or no chance at all.

To gauge respondents' ambiguity about risk perceptions, respondents were then asked if they were very sure, somewhat sure, somewhat unsure, or very unsure about their answers to the risk question. Following these two questions, respondents were asked to state quantitatively what they thought the chances were that someone from one of these million households would have a health problem someday because of pesticide residues in food. Respondents could choose: no chance, 1 in a million people, 1 in 100,000 people, 1 in 10,000 people, 1 in 100 people, 1 in 10 people, or certain to happen. They were then asked how sure they were about their quantitative assessment.

The perceived risk associated with the certified apples was measured differently. Respondents were asked to evaluate the percentage reduction in risk if all foods were certified for residue levels. Half the sample received a version that stated the food was government tested and certified to meet federal standards for pesticide residues. The other half was asked about food that was government tested and certified to be produced without pesticides. The federal standard was used to determine if consumers wanted tougher enforcement, but no change in standards. The no pesticide certification was used to determine if consumers wanted both tougher enforcement and tougher standards. The type of certification was randomly assigned to respondents based on the last digit of the respondent's phone number.

Instead of asking respondents how sure they were about the risk reduction from certification, we asked them how effective they thought the government testing and certifying would be in ensuring that foods had no pesticide residues above federal standards or was produced without pesticides.

Health risk perceptions were measured in terms of risk from residues on all foods, not only from apples. Risks from residues on apples are so small that it is impractical to develop units that respondents can easily interpret. Consequently, we assume that the risk from residues on apples is a constant percentage of total perceived risk. The problem with this approach is that risk is a function of both hazard and exposure, and exposure depends on how many apples one eats. Thus, the proportion of total health risk that is due to apples varies across consumers as quantity of apples consumed varies. For adults, apple consumption is a relatively small portion of the diet, so this assumption should not have a significant effect on the validity of our results. However, apple consumption by children is quite large. To account for this, our model includes a dummy variable for the presence of children in the household. We predict that the presence of children in the household has positive effect on the purchase of certified apples.

The sureness ratings that respondents gave on their risk perceptions were used as proxies for ambiguity about risk on regular food. We assume that the less "sure" someone is, the wider is his/her second-order probability distribution. One of the problems with this measure is that it assumes that the ordinal "sureness" scale employed in the survey is interpreted similarly by all respondents.

The effectiveness rating on risk reduction is an incomplete measure of ambiguity about risk reduction because it does not measure the change in perceived effectiveness. Thus, respondents were asked about their current trust that the federal government ensures standards are met. We assume that people who do not currently trust that the standard for pesticide residues is being met, **and** who feel that if the government tested and certified apples for their residue level that such a program would be effective are likely to experience the most ambiguity reduction when switching to the certified apples. A dummy variable reflecting this combination of beliefs is constructed and included in the choice model to reflect ambiguity reduction.

This type of dummy variable for ambiguity about risk reduction is incomplete because a person could believe the government is effective but that the risk standard is unacceptable. We measure standard acceptability by asking respondents if they trust that the government sets the same standards that the respondent would set.

The sample consisted of the telephone numbers of Michigan households generated by Survey Sampling, Inc. using random digit dialing. Interviews were attempted with 1730 telephone numbers during June and July, 1992. Of these, 1,003 were completed for a response rate of 67%. Respondents were adults over the age of 18 who did most of the food shopping for their household. The interviews were conducted by trained, experienced interviewers using computer automated telephone interview software (CATI) at the Institute for Public Policy and Social Research (IPPSR) at Michigan State University. The software made it possible to customize each interview and randomly assign different purchase scenarios to different subsamples.

Empirical Model

The decision to buy the certified apples is treated as a two-step process. The consumer must first decide whether or not to buy the certified apples. Once the decision to buy them has been made, he/she must decide how many to buy.

Limiting the range of the values of the dependent variable in the second stage to only the positive values of those who consumed the apples leads to a nonzero mean of the disturbance term and to biased and inconsistent least squares estimators. To deal with this, we estimate a Heckman two-stage model and use the results of the demand estimation in the second stage to calculate consumer surplus.

The general two-stage model of demand for certified apples estimated in this research is the following:

<u>Stage 1: PROBIT</u>

The following PROBIT model is run to determine the factors that affect the decision to select certified apples.

$$Z = \alpha_o + \alpha_{p_c} p_c + \alpha_{p_r} p_r + \alpha_{\pi^r} \pi^r + \alpha_{\Delta\pi(\%)} \Delta\pi(\%) + \alpha_{\Delta\pi(\%own)} \Delta\pi(\%own) + \alpha_{\epsilon^r} \epsilon^r + \alpha_{\Delta\epsilon} \Delta\epsilon + \alpha_M M + \alpha_S S + e \tag{16}$$

Stage 2: OLS

For households that choose certified apples:

$$Q = \beta_o + \beta_{p_c} p_c + \beta_{p_r} p_r + \beta_{\pi^c} \pi^c + \beta_{\Delta\epsilon'} \Delta\epsilon + \alpha_M M + \alpha_{S'} S' + e \tag{17}$$

where:

Z	=	a dummy variable defined as: Z=1 if $Y_i^* > 0$ (the household buys certified apples), Z=0 if $Y_i^* \leq 0$ (the household does not buy certified apples).
Q	=	the quantity of apples consumed
α_o	=	constant term in PROBIT equation
β_o	=	constant term in the demand equation
p_c	=	the per-pound price of certified apples
p_r	=	the per-pound price of regular apples
π^r	=	perceived baseline probability of an adverse health effect resulting someday because of pesticide residues in food when one consumes regular apples
$\Delta\pi(\%)$	=	perceived change (in percentage terms) in the probability of an adverse health effect resulting someday because of pesticide residues in food when one consumes certified apples
$\Delta\pi(\%\text{own})$	=	perceived change (in percentage terms) in the probability of an adverse health effect resulting someday because of pesticide residues in food when one takes actions to reduce pesticide residues in food
ϵ^r	=	perceived ambiguity about π^r (measured by "sureness": ϵ^r(SURE), trust in standard: ϵ^r(NTRSTSTD), or belief that government program to test and certify for pesticide residues would be effective, ϵ^r(VSEFF))
$\Delta\epsilon$	=	perceived change in ambiguity about π^r when switching to certified apples
M	=	Income
S,S'	=	demographic characteristics of the household (includes SCHOOL: number of years of schooling of respondent, INCOME: total annual household income, and UND18: dummy variable indicating presence of children in the household under the age of 18)
e	=	disturbance term

The results of three PROBIT specifications are presented in Table 1.

Table 1: PROBIT Results

	MODEL 1	MODEL 2
Dep Var:	Z	Z
Variable	**Coefficient (standard error)**	**Coefficient (standard error)**
α_o	0.29 (0.51)	0.15 (0.51)
p_r	2.27*** (0.60)	2.19*** (0.60)
p_c	-2.68*** (0.54)	-2.62*** (0.54)
SCHOOL	0.06** (0.03)	0.06** (0.03)
INCOME	0.00001** (0.000003)	0.00001** (0.000003)
UND18	0.42*** (0.12)	0.40*** (0.12)
π^r	0.32 (0.26)	0.29 (0.26)
$\Delta\pi$(%)	0.50** (0.23)	0.54** (0.23)
$\Delta\pi$(%OWN)	-0.56** (0.24)	-0.49** (0.24)
ϵ^r(SURE)	-0.35* (0.22)	
$\Delta\epsilon$	0.44* (0.24)	0.42 (0.28)
ϵ^r(NTRSTSTD)		0.19 (0.15)
ϵ^r(VSEFF)		0.14* (0.07)
% of buying HHs	72%	72%
Log (L)	-289.39	-290.95
χ^2	67.71	68.16
Pseudo R^2	0.10	0.10
% correct predictions	75	74

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Several goodness of fit measures suggest that both PROBIT models presented in Table 1 are significant. A likelihood ratio test of the hypothesis that all the coefficients are zero shows that both PROBIT models are highly significant. The χ^2 value for each model (67.71 with 10 degrees of freedom for model 1, and 68.16 with 11 degrees of freedom for model 2) is well above the critical value at 0.001 level of significance. Furthermore, both models make over 70% correct predictions. Although the pseudo R^2 are low for all the models, we hesitate to emphasize this measure of goodness of fit as Greene (1990) suggests that "values between zero and one have no natural interpretation" (Greene 1990, 682).

Factors Influencing the Decision to Purchase Certified Apples

The effect of ambiguity reduction on the demand for certified apples is tested using the variable $\Delta\epsilon$ in model 1 and model 2. This variable is positive and significant in model 1, indicating that ambiguity reduction is important in determining consumers' choices. The coefficient on this variable is not significantly different from zero in model 2.

The variable ϵ^r(**SURE**) in model 1 measures peoples' "sureness" about their estimate of the risk from residues on regular apples. ϵ^r(**NTRSTSTD**) is the measure of peoples' trust that the standard set by the government for pesticide residues in food (whatever that may be) meets the standard for pesticide residues. (ϵ^r(**NTRSTSTD**)$=1$ indicates a person does not trust that food meet the standards, 0 otherwise). Although the sign of the coefficient on ϵ^r(**SURE**) should be negative, the expected sign on ϵ^r(**NTRSTSTD**) is unclear. We assume that people who mistrust that the food they buy meets the federal standards for pesticide residues have higher ambiguity (indicating that the sign of its coefficient should be negative). However, this variable probably also captures their higher risk perception since people who feel that food does not currently meet the standard probably perceive higher levels of pesticide residues in their food. The sign on the coefficient might then be positive. This variable probably confounds the two perceptions; and the expected sign of its coefficient remains undetermined.

The "sureness" measure of ambiguity (ϵ^r(**SURE**)) in model 1 is significant and negative at the 10% level; the "trust" measure of ambiguity in model 2 (ϵ^r(**NTRSTSTD**)) is not significantly different from zero.

In both models, the "type" of certification one received did not influence the decision to buy the apple. The decision to purchase the certified apples was not influenced by whether one received the "produced without pesticides" certification, or the "this product meets federal standards for pesticide residues" certification.

The presence of the certification, regardless of the exact content, may be enough to assuage peoples' fears about pesticide residues. In other words, there is a sort of "warm glow" effect (Andreoni 1990, Kahneman and Knetsch 1992). People may be willing to pay for the certified apple as long as it gives them **some** improvement over the regular apples. The "quantity" of the improvement may not be important as long as people think they are getting **some** reduced risk.

The results of the second-stage demand estimation are presented in Table 2. They show that the most important factor determining the quantity of certified apples, once the decision to buy them has been made, is household size. Household size (**HHSIZE**) is significant and positive. The model also demonstrates that the demand for certified apples is price and income inelastic.

Table 2: Second-Stage Demand Equation with Ambiguity measured as ϵ^r(SURE)

	MODEL 1
Dependent Variable:	QC
Variable	**Coefficient (standard error)**
CONSTANT	15.40 (9.267)
p_r	22.18 (20.09)
p_c	-27.65 (20.09)
HHSIZE	3.68^{***} (1.22)
INCOME	0.0001 (0.00001)
π^c	30.22^{**} (13.52)
$\Delta\epsilon$	-5.74 (4.20)
λ	10.74 (12.79)
Log (L)	-1889.38
Corrected std. error	32.6
Mean of LHS	26.1
Adjusted R^2	0.03

* significant at the 10% level
** significant at the 5% level
*** significant at the 1% level

Because the survey did not solicit the amount of ambiguity associated with the certified apple, the models use ambiguity reduction as an associated measure of the ambiguity. This variable is not significantly different from zero in determining the quantity of apples purchased in either model.

The inverse Mill's ratio was included in the second-stage demand equation even though its coefficient was insignificant. The insignificance of the inverse Mill's ratio is probably due to the correlation between the Mill's ratio and the other variables in the equations, since the ratio is itself a function of some of those variables. Since a large proportion of households did not choose certified apples, the censoring problem is probably more important than the multicollinearity that arises by including the inverse Mill's ratio.

Willingness to Pay for Certification

The calculations of the willingness to pay for pesticide-residue certification is based on model 1. This model uses the measure of ambiguity most closely related to the definition of ambiguity used throughout the paper.

We use the results of model 1 in the first and second stage to calculate the willingness to pay for certification as discussed in the next section. Because the approach used to estimate consumer surplus depends on the results from both the PROBIT and the second-stage estimation, the WTP calculations are strongly influenced by the factors that affect the choice to buy certified apples.

We use Hellerstein's (1992) measure of expected consumer surplus:

$$E[CS] = \int_{p_{obs}}^{p_{choke}} (\Phi * X\beta + \sigma\phi)\, dp \qquad (18)$$

where σ is the standard deviation of the disturbance term, e, Φ and ϕ are evaluated at $(\beta X_i/\sigma_i)$, and P_{obs} is the observed price at which the integral is evaluated, and P_{choke} is the value at which demand approaches zero (selection of this price is described below). This measure of consumer surplus explicitly accounts for the fact that the choke price depends on the stochastic term.

We also follow Hellerstein and use the cutoff price from the linear deterministic model: if the linear deterministic model is $Y = X\beta$, the cutoff price is $\frac{-(\beta X - \beta_{P_c} P_c)}{\beta_{P_c}}$.[4]

The value of equation 18 is calculated for each respondent, at a specified price for regular and certified apples. This calculation yields the total surplus associated with the purchase of certified apples. Since the dependent variable in the demand equation is the quantity of certified apples purchased in a fall season; the generated surplus measure is the surplus associated with the purchase of certified apples **in the fall quarter**. The surplus per pound of certified apples is the fall surplus divided by the expected number of apples bought in the fall season. This amount is estimated using the integrand of equation 18.

The estimates of the willingness to pay for certification are shown in Table 3 through Table 5. Table 3 shows the welfare measures on a "per pound" basis, Table 4 shows the measures on a "per year" basis. The "base" row is the willingness to pay for certification using the observed values for all variables. Based on the data from this survey, we estimate that people are willing to pay $0.31 (32%) more per pound for the certified apple than what they pay

[4] Hellerstein (1992) notes that this is **not** the price at which expected demand goes to zero, and is therefore not necessarily better than some other value (such as the maximum price observed in the sample).

for the regular apple. This is within the range of the estimates obtained in the van Ravenswaay and Hoehn study (1991) where they estimated the average added price per pound was between \$0.24 and \$0.38, depending on the exact content of the certification.

Table 3: Willingness to Pay for Certification and Sensitivity Analysis[5] (\$ per pound, per household)

SCENARIO	**MODEL 1 (ambiguity measured with ϵ^r)**
Base Case	**\$0.31**
Scenario 1	\$0.28 (-10% from base)
Scenario 2	\$0.32 (+3% from base)
Scenario 3	\$0.31 (+0% from base)

Table 4: Willingness to Pay for Certification (\$ per year, per household)

SCENARIO	**MODEL 1 (ambiguity measured with ϵ^r)**
Base Case	**\$7.06**

[5] The analysis is conducted at the following prices:

\$0.98 for regular apples
\$1.04 for certified apples

See text for discussion of price selection

Table 5: Changes in WTP for Certification due to Changes in Sureness

Sureness Level	Willingness to Pay for Certification ($ Per Pound)
Very Sure	$0.34 (+9% from base)
Somewhat Sure	$0.31 (+0% from base)
Somewhat Unsure	$0.28 (-10% from base)
Very Unsure	$0.26 (-16% from base)

The scenarios in Table 3 apply the coefficients from the base model to the actual values of the variables, while changing the values of the ambiguity variables. The scenarios are as follows:

Scenario 1. All consumers are either "very unsure" or "somewhat unsure" about their risk estimate

Scenario 2. All consumers are either "somewhat sure" or "very sure" about their risk estimate

Scenario 3. All consumers believe a federal program to test and certify food for pesticide residues would be either "very effective" or "somewhat effective."

The average willingness to pay for the certification on apples under scenario 1 is $0.28. In this scenario everyone is either "very unsure" or "somewhat unsure." This is $0.03 (or 10%) less than the under the base scenario in which 29% of the respondents were "very unsure" or "somewhat unsure." Baseline risk was not changed in this scenario, indicating that perhaps people simply want to know what they are getting in terms of safety when they buy apples. They get that with the certified apple; they may not be getting it with the regular apple. The results conform with the hypothesis that people with higher initial ambiguity should be willing to pay less for certification.

If all respondents felt sure about their estimates (they were either "somewhat sure" or "very sure" as in Scenario 2) willingness to pay for the certification increases by $0.01 (+3%) from the base case and $0.04 (+14%) from scenario 1 in which all respondents are "somewhat unsure" or "very unsure."

Scenario 3 shows that if everyone were convinced of the effectiveness of a federal program to test and certify food for residue levels, willingness to pay for the certified apple would be the same as in the base case ($0.31 per pound).

Table 5 shows the change in WTP due to changes in the level of sureness. The results show that, as hypothesized, the willingness to pay for certification decreases with baseline ambiguity. Perceptions of high baseline ambiguity probably drive the choice to buy the certified apples, although once that decision has been made, neither baseline ambiguity nor changes in ambiguity help determine the quantity purchased.

There is little doubt that consumers feel some uncertainty about the risks they face from pesticide residues in apples: 29% of the survey respondents said they were either "somewhat unsure" or "very unsure" about their risk estimate. Similarly, a large percentage of respondents said they do not trust that the government sets the same standards they would, nor do they trust that once the standards are set, all foods meet those standards.

However, measures of baseline ambiguity are imperfect at best. When we use "trust that the standard is being enforced" as a proxy for ambiguity, for example, we are probably confounding two opposing forces. The trust in the standard variable probably captures the uncertainty about the risk estimate, but it probably also captures some of the perception of the change in risk associated with the certified apple. That is, when people feel that the standard is being enforced, they probably also feel that their risks are reduced (both baseline ambiguity **and** changes in risk are influenced by trust).

Conclusions

The results of this research support the conclusion that ambiguity about risks is an important factor in modeling consumer willingness to pay for reduced pesticide residues in food. Since the results are limited to the case of consumers' choices about fresh apples and a labeling policy for pesticide residues, application to other foods and other policy scenarios are needed to verify this conclusion.

Measuring ambiguity accurately is probably the biggest obstacle researchers face in terms of trying to understand how ambiguity perceptions affect the willingness to pay for certification and for reduced ambiguity. The measures of ambiguity developed in this research are proxies for the variance of the second-order probability distribution of an outcome. However, other measures of ambiguity need to be developed and applied.

This research finds that people are willing to pay significant amounts to receive the signal that something has been done about pesticide residues in food to protect their health. The estimate of WTP is similar to estimates from other studies.

The difference in willingness to pay across ambiguity levels suggests that a labeling policy stating that a product meets the current standards for pesticide residues could increase consumer welfare by reducing ambiguity. Although testing and certifying products would be required for such a policy, the cost of such a policy would probably be low since most foods already meet the standards.

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