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Consumers' Valuation of Insecticide Use Restrictions: An Application to Apples

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Economic assessments of pesticide regulations typically focus on producer impacts and generally ignore possible changes in product demand. These changes may be nonnegligible if real and/or perceived product attributes change. We measure consumers' willingness to pay (WTP) for the elimination of one insecticide and also a whole group of insecticides in apple production using a multiple-round Vickrey auction. The data are analyzed using nonparametric statistical tests and a double-hurdle model. Our findings show that consumer perceptions of product attributes change if pesticides are removed from production, and this is reflected in WTP changes. WTP is shown to be income elastic.

Key words: consumer experiment, cosmetic quality, double-hurdle model, food safety, pesticide residues, Vickrey auction, willingness to pay

Introduction

Economic assessments of pesticide regulation typically focus on producer impacts and generally ignore possible changes in product demand (see, e.g., Lichtenberg, Parker, and Zilberman; Rice-Mahr and Moffit). These changes may be nonnegligible if real and/or perceived product attributes change. Studies focusing on the demand side typically elicit hypothetical willingness to pay (WTP) for a complete removal of pesticide use or of pesticide residues (Ott; Misra, Huang, and Ott; Weaver, Evans, and Luloff).[1] Regulators, however, rarely propose complete elimination of pesticides. Instead, they seek to eliminate or limit the use of specific compounds or classes of compounds. Inferences from the existing studies on consumers' WTP for a partial removal of pesticides may not be valid since stepwise elimination may not result in overall reduction of pesticide use when substitute pesticides are available. Consumers who are aware of the substitution possibilities may place little value on the fact that a specific pesticide is not used.

The Food Quality Protection Act (FQPA) of 1996 changes the approach to pesticide risk assessments. Rather than considering the risk from pesticide exposure on a

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[1] Van Ravenswaay and Hoehn estimated demand changes for apples in the Alar crisis based on market data, and used the data to infer a WTP to avoid Alar.

pesticide-by-pesticide basis, the total risk from all pesticides with a common mode of toxic action now must be considered. As a result of this change, organophosphate insecticides currently are being subjected to increased scrutiny (Environmental Protection Agency; Wiles, Davies, and Campbell). Organophosphates interfere with the transmission of nervous impulses, leading to a spectrum of cholinergic symptoms, and are classified as neuroactive insecticides (NAI).[2] Of particular concern are the possible long-term effects on brain function due to chronic exposure to these pesticides in early childhood (National Research Council; Wiles, Davies, and Campbell).

To study consumers' responses to possible regulation of neuroactive insecticides, we measure WTP for their elimination in apple production. In particular, we consider a cessation of use of one NAI, namely azinphos-methyl (APM), and the group of all NAI. APM was chosen due to its particularly high toxicity and its central role in current apple production systems (U.S. Department of Agriculture/National Agricultural Statistics Service).[3]

This investigation differs from many other WTP studies in the manner in which values are elicited. Past studies typically have used contingent valuation in mail surveys (Byrne, Gempesaw, and Toensmeyer; Misra, Huang, and Ott) or interviews (Ott; Weaver, Evans, and Luloff). Following methods described by Shogren et al., we create a market for apples not treated by either APM or the group of NAI. In this artificial market, participants are endowed with one bag of apples produced using standard methods (i.e., with pesticides), and are given an opportunity to bid for an upgrade to apples produced without either APM or all NAI. Bids are elicited in a multiple-round Vickrey auction in which participants receive price information from the previous round. We also elicit bids in a final single-round Vickrey auction.

This article proceeds with a description of the experiment employed. We then summarize the results and analyze the data using statistical tests and a double-hurdle model. We conclude with a discussion of the implications of our findings in view of the 1996 FQPA.

Experimental Design

Experimental studies to elicit consumers' WTP for quality changes in food products have been employed by a number of researchers, including Buhr et al., Melton et al., and Shogren et al. We follow their methodology in using a multiple-round Vickrey (i.e., second-price) auction that combines the advantage of the true WTP revealing property of the Vickrey auction with repeated market experience. To control for wealth effects, only one trial, selected at random, is usually enforced. As in Melton et al., our experiment features simultaneous valuation of multiple attributes (pesticide use and appearance), but in contrast to their experiment, we include an initial endowment with

[2] Neuroactive insecticides act by inhibiting acetylcholinesterase, the enzyme that degrades acetylcholine, the messenger of the parasympathetic nervous system. This results in high acetylcholine levels, exaggerating the normal functions of the parasympathetic system. Acute symptoms can include nausea, vomiting, and irregular heartbeat. This group of insecticides is of high priority in the implementation of FQPA.

[3] Wiles, Davies, and Campbell conclude that one of the main sources of unsafe exposure of children to risks from organophosphate insecticides occurs via apple products, and that azinphos-methyl is among the five organophosphate insecticides that present the greatest risk.

the base quality. Details of the experimental procedure are explained in the following paragraphs.[4]

To create the artificial market, we first endowed each participant with a 2.5-pound bag of Washington State extra fancy red delicious apples. In the auction procedure, participants were asked to bid the maximum amount they were willing to pay to exchange their endowed bag for each of four alternative bags. Each of the four alternatives also contained 2.5 pounds of Washington State red delicious apples, but their pesticide treatment histories differed. Two of the bags offered for exchange contained apples that received a conventional pesticide treatment but no APM. The other two bags contained apples that had not been treated by any NAI. The two bags within each of the pesticide treatment categories also differed in terms of appearance, with apples in one bag showing some cosmetic damage and the other bag being visually identical to the bag of endowed apples. Participants therefore faced the problem of evaluating four different qualities in comparison to a base endowment. Quality is defined as a two-dimensional vector of cosmetic and food safety attributes, the latter being uncertain. WTP for exchanging the initially endowed bag should be positive if quality attributes of the alternatives are deemed superior compared to the base endowment.

Participants were selected using a random sample from a midwestern university town. The experiments were run in four separate groups with a total of 54 participants. Prospective households were contacted by phone, and the person responsible for most of the grocery shopping in the household was invited to the experiment. A participation remittance of $30 was offered and was paid to participants in cash upon their arrival at the study site.

The complete experiment consisted of six steps. In Step 1, we administered a short questionnaire to collect demographics and information about apple consumption, attitudes toward food and pesticide policy issues, and experience with organic foods. Following Shogren et al., we then familiarized participants with the multiple-round Vickrey auction procedure by conducting an auction using candy bars (Step 2). The preference revelation property was emphasized by explaining why it was in a participant's best interest to bid his/her true valuation in the second-price auction. In the candy bar auction, participants bid to upgrade from an endowed candy bar to each of four alternatives. Both the binding round (one of three) and the candy bar to be sold within that round (one of four) were randomly selected at the end of the bidding procedure, and the winning bidder paid cash for the upgrade.

Participants were given their bags of apples in Step 3. To set the stage for the experimental bidding, a questionnaire for hypothetical bids was administered. It included three questions about how much (as a percentage) participants would be willing to pay for apples not treated with (*a*) APM, (*b*) NAI, and (*c*) any pesticides, assuming the apples were cosmetically unblemished. The third question served to remind participants that apples not treated with APM or NAI could be treated with other pesticides.[5] In Step 4, we provided the following information about pesticides and descriptions of the apples to be auctioned:

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[4] A complete set of experimental instructions is available from the senior author on request.

[5] This is also in line with recommendations by the National Oceanic and Atmospheric Administration (NOAA) Panel on Contingent Valuation. The Panel suggests that if CVM-type methods are used, then participants should be made aware of substitution possibilities.

All the apples in this experiment are of the same variety (Red Delicious) and were grown in Washington State. All bags weigh 2.5 pounds. *Azinphos-methyl is the most widely applied insecticide in apple production. It is, like most other insecticides, a neuroactive pesticide* that works by interfering with the transmission of nervous impulses. No pesticides that might not have been used on the average apple you buy in the grocery store have been used on the apples in this experiment.

TYPE A (bag 1)	**TYPE B (bag 2 and bag 3)**	**TYPE C (bag 4 and bag 5)**
These are apples that have been produced under the same conditions as those you would buy in your grocery store. Pesticides, including azinphos-methyl, have been used in their production.	These are apples produced without using the commonly used neuroactive pesticide, azinphos-methyl.	These are apples produced without using any neuro-active pesticides. Other pesticides might have been used.

The apples in bags 2 and 4 were similar in appearance to the apples of type A (bag 1), whereas apples in bags 3 and 5 were of lower cosmetic quality. Participants were not told which bags were regarded as being of lower cosmetic quality, but were simply allowed to examine the apples for themselves. All bags were transparent, so there was no impediment to viewing the apples.

Step 5 was the multiple-round Vickrey auction in which participants were endowed with type A apples and were asked to bid to upgrade from type A apples to each of the four alternatives. The auction followed the same procedure as that used for the candy bars, with the implication that the binding round would be chosen at the conclusion. Participants were told that only one bag of apples, selected at the end of the experiment, would be sold. Following each round of bidding, the second-highest bid and the identification number of the highest bidder were announced for each bag. After the third trial, the following additional information was provided to the participants:

> Insecticides are the most important pesticide group in apple production. In fact, 98% of U.S. apple acreage is treated with insecticides. Almost all insecticides used in apple production affect the nervous systems of insects. These are called 'neuro-active' pesticides and they work by interfering with the transmission of nervous impulses.
>
> Azinphos-methyl, a neuroactive pesticide, is the most widely applied insecticide. It is used on 86% of apple acreage and it is one of the neuroactive pesticides with the highest toxicity. Many close substitutes for azinphos-methyl are available. If azinphos-methyl were not allowed for use, it would likely be replaced by other neuroactive pesticides, but these neuroactive pesticides are likely less toxic.
>
> There are pest control methods available that can control insect pests without the use of neuroactive pesticides. They are not widely used in practice because they are relatively new and are also more expensive. Using these methods instead of neuroactive insecticides would increase the costs of producing apples and increase the price of apples. Bag 4 and bag 5 have been produced using these alternative methods.

Bidding then resumed and continued through trial 6. After the sixth bid, participants were told that the seventh and final trial would, in fact, be the binding trial. We included this feature to investigate possible differences in bidding behavior between a multiple-round auction with random selection of the binding trial and one-shot versions of the Vickrey auction after market experience. While there is no evidence to suggest that random selection of the binding trial is not incentive-compatible, we determined that the issue merited this simple test. Following the seventh bid, the highest bidder exchanged his/her bag of apples for the randomly selected bag and paid an amount equal to the second-highest bid. Finally, Step 6 involved an exit questionnaire asking participants to clarify their motivation—i.e., why they had or had not bid for each of the bags.

Results

The Sample

Table 1 presents the demographic characteristics of the sample. We invited the person primarily responsible for the household grocery shopping; of the 54 participants, females were in the majority. The average age was 43 years, most people had some college education, and 46% had a college degree. This is well above average for the region, but typical of a university community. The same holds true for the annual mean household income of $46,000. Few subjects came from households with children under five years of age.

In Step 1 of the experiment, we asked the participants to rank (on a scale of 1–5) their concern about pesticide use in food production, as well as their pesticide policy preference (choosing from four policy options provided) (table 1). The latter question also was used in a questionnaire employed by Ott. Overall, 21 of our 54 participants indicated a high degree of concern about pesticide use (rankings of 4 or 5), and 16 of these individuals expressed a strong preference for a much stricter pesticide regulation (policy options 3 or 4). Participants also were asked if they would be willing to buy apples with insect damage. The majority (30) answered no, 20 said maybe, and only four replied that they would.

Bids to Avoid APM and NAI

Table 2 provides some statistics on bids obtained in the first and final trials. In the first trial, bids averaged $0.22 for the upgrade to bags 2 and 4, the apples with no cosmetic damage. For apples with cosmetic damage, bids were much lower. In the seventh trial, participants were, on average, willing to pay a premium of $0.34 for apples not treated by APM, and $0.45 for a similar bag not treated by any NAI.

At the time we conducted this experiment, the price for these apples in local stores was about $1 per pound. Our average bids, therefore, ranged from 9% of market value in trial 1 up to about 18% in the final bidding trial. Although this value seems relatively high, it compares to results obtained by van Ravenswaay and Hoehn. They estimated an average WTP to avoid Alar in fresh apples ranging from 11% in 1984 (the first Environmental Protection Agency announcement of possible carcinogenicity of Alar) to 31% in 1989 (climax of the Alar controversy). Research on the price differential for organic produce also has shown that premia can be quite substantial. Using actual market data, Thompson and Kidwell report a premium of 42% of market value for organic red delicious apples.

Table 1. Summary Statistics of the Experiment Sample

Variable	Description	Mean	SD
SEX	Sex (0 = female; 1 = male)	0.26	0.44
AGE	Age (years)	42.80	15.05
EDUC	Education (1 = grade 8; 2 = grades 9–11; 3 = high school graduate or GED; 4 = some technical trade or business school; 5 = some college, no degree; 6 = B.S./B.A.; 7 = some grad work, no degree; 8 = M.S./M.A.; 9 = Ph.D.)	5.44	1.53
EMP	Employment (0 = not employed; 1 = employed)	0.87	0.34
INC	Annual household income ($000s)	46.02	26.54
CHILD	Child(ren) age 5 and below in household	0.15	0.36
ORG	Organic shopping (1 = never; 2 = sometimes; 3 = always)	1.72	0.45
FREQ	Frequency: How often do you eat apples? (Scale of 0–5, where 0 = never; 5 = every day)	2.38	1.34
AEATER	Number of apple eaters in household	2.48	1.44
POLICY	Policy Opinion: 1 = Current pesticides are safe and consumer fears are unwarranted. 2 = Pesticides can be used safely, but there should be greater testing. 3 = Some pesticides should be banned and greater restrictions should be placed on remaining pesticides. 4 = All pesticides should be banned.	2.33	0.67
Variables Related to Issues of Concern: (Scale of 1–5, where 1 = not concerned; 5 = very concerned)			
PESTCONC	Concern about food grown using pesticides	3.20	1.25
FPOICONC	Concern about food poisoning	3.81	1.12
PRCONC	Concern about food prices	3.74	1.20
Variables Related to Importance of Apple Attributes: (Scale of 1–5, where 1 = not important; 5 = very important)			
FLAVOR	Flavor	4.67	0.51
APRICE	Price	3.67	1.17
DAM	Damage	4.15	1.02
APEST	Pesticide use in apple production	2.61	1.27

Note: Total number of participants in sample = 54.

Table 2. Summary Statistics of Bids (first and final trials)

Description	BAG 2 No APM; No Cosmetic Damage	BAG 3 No APM; Cosmetic Damage	BAG 4 No NAI; No Cosmetic Damage	BAG 5 No NAI; Cosmetic Damage
Auction, Trial 1:				
Average bid	\$0.22	\$0.08	\$0.22	\$0.14
Median bid	\$0.05	\$0.00	\$0.10	\$0.00
Second-highest bid	\$1.25	\$0.60	\$1.00	\$1.00
Average bids w/o zeroes	\$0.43	\$0.30	\$0.45	\$0.45
Number of zero bids	26	39	27	37
Inter-group variation	$s^2 = 0.0245$	$s^2 = 0.0483$	$s^2 = 0.1376$	$s^2 = 0.0618$
Auction, Trial 7:				
Average bid	\$0.34	\$0.21	\$0.45	\$0.34
Median bid	\$0.10	\$0.00	\$0.25	\$0.10
Second-highest bid	\$2.10	\$1.75	\$2.50	\$1.50
Average bids w/o zeroes	\$0.62	\$0.66	\$0.69	\$0.66
Number of zero bids	24	37	19	26
Inter-group variation	$s^2 = 0.1876$	$s^2 = 0.1707$	$s^2 = 0.3914$	$s^2 = 0.2605$

A relatively large number of participants were not willing to pay any premium for the reduction in pesticide use. In particular, 19 of the 54 participants consistently bid zero for all of the potential upgrades. Due to the large number of zero bids, median bids are consistently lower than the mean bids. As expected, more participants declined to pay a premium when cosmetic damage was present. Furthermore, with cosmetic damage, the number of zero bids was higher when only one pesticide was removed (table 2). For participants with positive WTP, the average premium ranged from about \$0.40 in the first trial to about \$0.66 in the final trial.

The development of the average bid for each bag is illustrated in figure 1. It shows an upward trend in the average bid for the early trials, but a stabilizing of the bids after trial 4. The set of individuals who gave bids of zero stayed fairly constant for type B apples (no APM), and decreased considerably for the type C apples (no NAI). Figures 2a and 2b graph the median bids for each bag across trials. Clearly, changes occur mostly for type C apples after the release of additional information.

Performance of the Multiple-Round Vickrey Auction with Random Selection of the Binding Trial

The experimental design permits testing of a number of hypotheses concerning the performance of auction markets as a means of revealing consumer WTP. The additional information after trial 6, informing participants that the seventh trial would be binding, provides an opportunity to discern whether the participants viewed the randomization of the trial selection rationally and thus bid their true WTP in each trial. Serious doubts

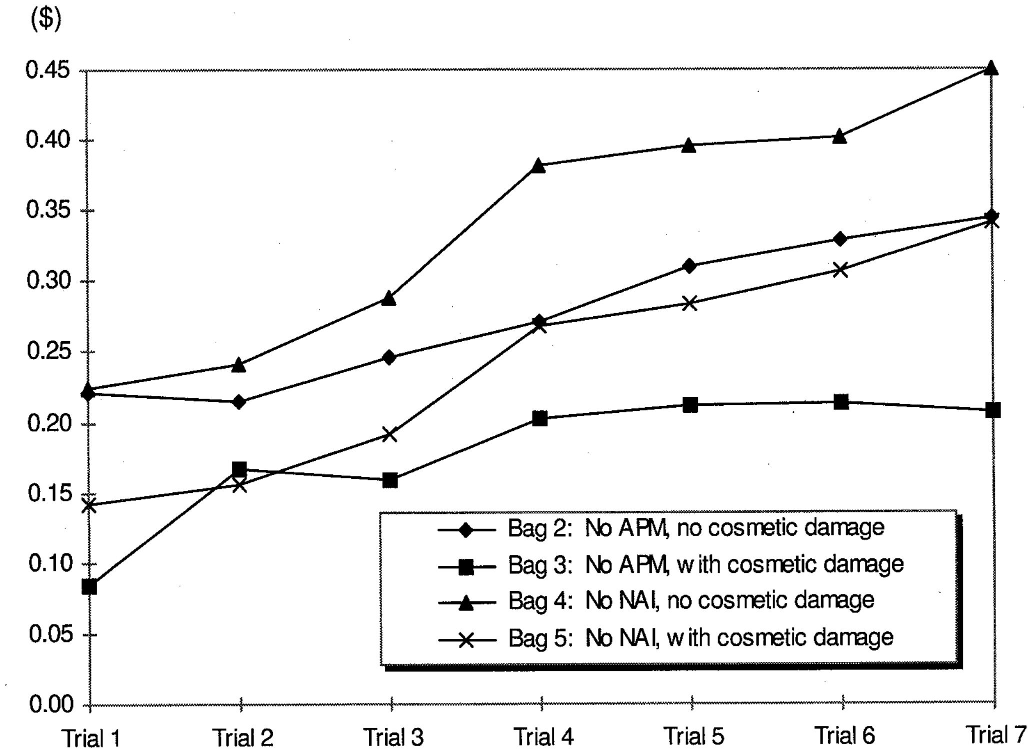

Figure 1. Average bids across trials

would be cast on the true WTP revelation property of the repeated Vickrey auction if, subsequent to receiving that information, subjects were to change their bids substantially. Figures 1 and 2 suggest that bids are relatively stable over trials 4, 5, and 6, but a number of participants continued to vary their bids. Of the 216 bids, 54 changed between trials 4 and 5, 46 changed between trials 5 and 6, and 54 changed between trials 6 and 7.

We tested the hypothesis of no change in the medians of the distributions of trials 6 and 7 using an ordinary sign test and Wilcoxon's signed rank test (Gibbons). Tests about the median are particularly useful here as we do not need to make further distributional assumptions about the data-generating process. The tests take the pairwise arrangements of the two samples into account. While the ordinary sign test only takes account of the signs of deviations from the median, Wilcoxon's test also uses the magnitudes of the deviations, thereby strengthening the power of the test. However, the maintained hypotheses of Wilcoxon's test are also more restrictive in that symmetry of the distribution is assumed. For both tests, we form the difference between the bids in trials 6 and 7 for each individual and each bag. The ordinary sign test then counts the numbers of positive and negative differences and compares their distribution to a binomial distribution with $p = 0.5$. Wilcoxon's signed rank test assigns ranks to those differences according to their absolute value. The sum of positive and negative ranks is compared to tabled values of the test distribution under the null.

Table 3 shows the statistics for trials 6 and 7 for each bag, where $\bar{x}$ denotes the sample mean, m is the sample median, and s^2 is the sample variance. The results of the paired sample tests show that the announcement about the binding trial had no

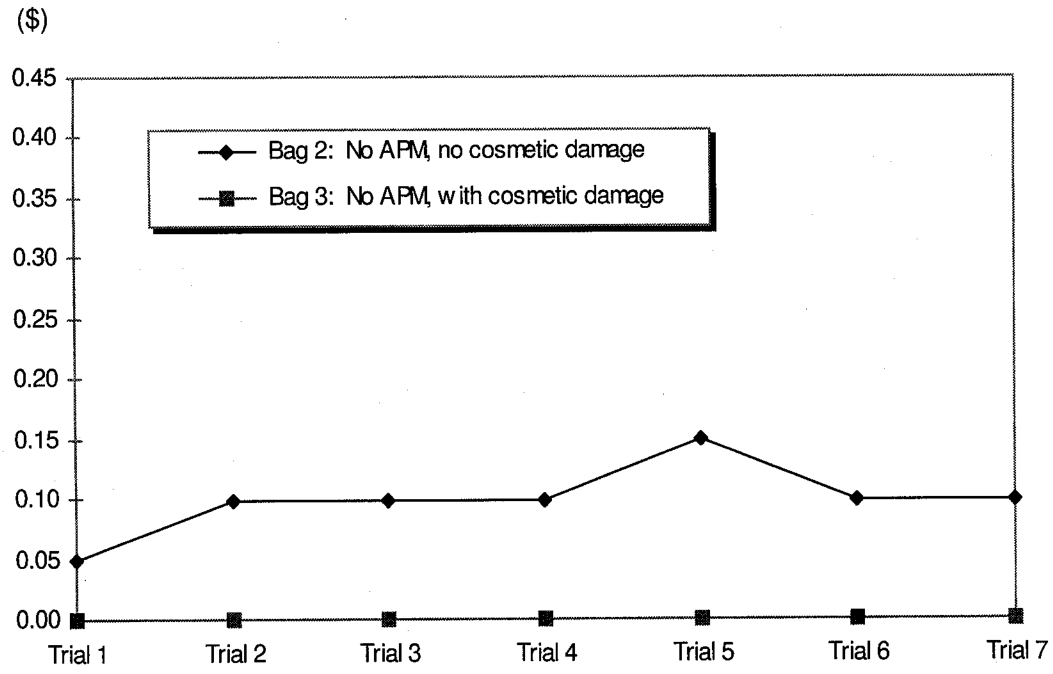

Figure 2(a). Median bids for bags 2 and 3 across trials

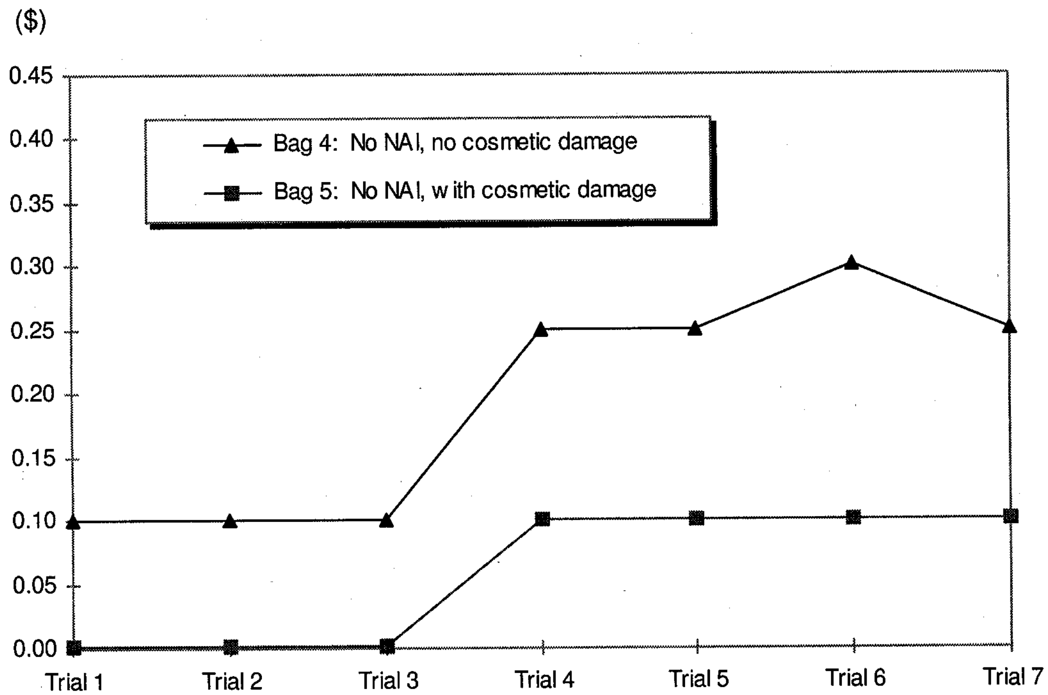

Figure 2(b). Median bids for bags 4 and 5 across trials

Table 3. Statistical Comparison of Trials 6 and 7: Performance of the Repeated Vickrey Auction

Bags	Trial 6	Trial 7	Sign Test (p-Value)	Wilcoxon Test (p-Value)
Bag 2	$\bar{x} = 0.3035$ $m = 0.10$ $s^2 = 0.4682$	$\bar{x} = 0.3435$ $m = 0.10$ $s^2 = 0.5536$	0.804	0.187
Bag 3	$\bar{x} = 0.2096$ $m = 0.00$ $s^2 = 0.4682$	$\bar{x} = 0.2065$ $m = 0.00$ $s^2 = 0.4505$	0.727	0.889
Bag 4	$\bar{x} = 0.3928$ $m = 0.30$ $s^2 = 0.5452$	$\bar{x} = 0.4498$ $m = 0.25$ $s^2 = 0.6546$	0.629	0.097
Bag 5	$\bar{x} = 0.2862$ $m = 0.10$ $s^2 = 0.4107$	$\bar{x} = 0.3407$ $m = 0.10$ $s^2 = 0.5537$	0.267	0.114

Note: $\bar{x}$ denotes the sample mean, m is the sample median, and s^2 is the sample variance.

significant effects, although Wilcoxon's test is inconclusive for bag 4.[6] We therefore conclude that the results of the multiple-round Vickrey auction with random selection of the binding trial (as in trials 4–6) are consistent with the results of the final single-shot auction after market experience.

Effect of Information

The other hypothesis we test is whether or not the information about pesticides, supplied following the third bidding trial, had an impact on bids. For the first three trials, the only information about pesticides entailed the descriptions of the different types of apples. We compare the bids from trials 3 and 4, again using an ordinary sign test and Wilcoxon's signed rank test (table 4).[7] The tests clearly reject a zero median for the distribution of the bid differences for bags 4 and 5 (no NAI). Learning about the substitution possibilities between pesticides within the group of NAI—i.e., replacing APM by other NAI—seems to have motivated participants to increase their bids for a complete removal of the entire group. The tests for bags 2 and 3 are somewhat inconclusive. Informing subjects that APM might be replaced by less toxic NAI did not result in clearly significant changes in WTP.

Table 5 offers another way to look at the effect of information about pesticides. Here we test for a median difference between bags 2 and 4 (no cosmetic damage), and bags 3 and 5 (cosmetically damaged) before and after the release of information. The results

[6] Wilcoxon's test also assumes symmetry of the distribution. A rejection of the null hypothesis under the Wilcoxon test, but not under the sign test, would indicate a rejection of symmetry rather than a rejection of a zero median in the differences.

[7] To ensure that the differences found between trial 3 and trial 4 did not stem from an increasing trend in the auction bid, we also tested the bid data from trial 2 versus trial 3 and did not find any significant differences at the 0.05 significance level.

Table 4. Statistical Comparison of Trials 3 and 4: Effect of Information

Bags	Trial 3	Trial 4	Sign Test (p-Value)	Wilcoxon Test (p-Value)
Bag 2	$\bar{x} = 0.2463$ $m = 0.10$ $s^2 = 0.3301$	$\bar{x} = 0.2717$ $m = 0.10$ $s^2 = 0.3857$	0	0.190
Bag 3	$\bar{x} = 0.1583$ $m = 0.00$ $s^2 = 0.3516$	$\bar{x} = 0.2028$ $m = 0.00$ $s^2 = 0.4963$	0.118	0.099
Bag 4	$\bar{x} = 0.2883$ $m = 0.10$ $s^2 = 0.4755$	$\bar{x} = 0.3816$ $m = 0.25$ $s^2 = 0.5415$	0	0
Bag 5	$\bar{x} = 0.1920$ $m = 0.00$ $s^2 = 0.2685$	$\bar{x} = 0.2906$ $m = 0.10$ $s^2 = 0.3609$	0	0.002

Note: $\bar{x}$ denotes the sample mean, m is the sample median, and s^2 is the sample variance.

Table 5. Statistical Comparison of "No APM" versus "No NAI"

Trials	No APM	No NAI	Sign Test (p-Value)	Wilcoxon Test (p-Value)
Trial 3	**Bag 2** $\bar{x} = 0.246$ $m = 0.10$ $s^2 = 0.330$	**Bag 4** $\bar{x} = 0.288$ $m = 0.10$ $s^2 = 0.475$	0.500	0.596
Trial 3	**Bag 3** $\bar{x} = 0.158$ $m = 0.00$ $s^2 = 0.352$	**Bag 5** $\bar{x} = 0.192$ $m = 0.00$ $s^2 = 0.291$	0.124	0.156
Trial 4	**Bag 2** $\bar{x} = 0.272$ $m = 0.10$ $s^2 = 0.386$	**Bag 4** $\bar{x} = 0.382$ $m = 0.25$ $s^2 = 0.541$	0.067	0.054
Trial 4	**Bag 3** $\bar{x} = 0.203$ $m = 0.00$ $s^2 = 0.496$	**Bag 5** $\bar{x} = 0.269$ $m = 0.10$ $s^2 = 0.416$	0.044	0.025

Note: $\bar{x}$ denotes the sample mean, m is the sample median, and s^2 is the sample variance.

suggest that WTP to avoid APM or NAI was not significantly different before the release of information. Following the release of information (i.e., in trial 4), those differences became significant.

Considering this result as an indication of consumers' perception of the new pesticide regulation according to the 1996 Food Quality Protection Act, bids for bags 2 and 3 can be interpreted as participants' valuation of a single pesticide use restriction as it would have occurred prior to the FQPA. Bids for bags 4 and 5, on the other hand, express consumers' preferences for a use restriction on all pesticides sharing a common mode of toxic action. The finding that participants, once aware of substitution possibilities, place a higher value on reducing the overall use of pesticides with a common mode of toxic action indicates support for the new risk regulation legislated in the FQPA.

Estimating Consumers' WTP for a Partial Reduction of Pesticide Use

The Double-Hurdle Model

We analyze the WTP using a double-hurdle procedure. Introduced by Cragg, the double-hurdle model is suitable for estimation of data sets with truncated dependent variables such as the WTP values that we have elicited. The model is flexible in that explanatory variables can explain both the likelihood of a positive observation and its conditional mean (see Yen and Jones for an application to food consumption). In the case of WTP studies for reduced pesticide use, risk perceptions and attitudes determine the desirability of goods with altered food safety characteristics—the first hurdle. Once a good seems desirable, an individual has to decide if, and how much, money should be spent on the choice—the second hurdle.

Let r_i be the variable representing the desirability of buying "reduced pesticide" food products for consumer i, and let WTP_i be the amount spent on the purchase. Then for each consumer:

(1a) $$r_i = \mathbf{X}_{1i}\beta + u_{1i};$$

(1b) $$WTP_i = \mathbf{X}_{2i}\gamma + u_{2i}.$$

Here, $\mathbf{X}_{1i}$ and $\mathbf{X}_{2i}$ are the sets of explanatory variables determining the desirability to buy and WTP, respectively, while β and γ are the parameter vectors to be estimated. The error terms in each equation, u_{ji}, are assumed to be normal with variances of unity and σ^2, respectively. The random variable r_i is not directly observable; one can only observe if WTP is positive, and then conclude that r_i has to be greater than a certain threshold which can, without loss of generality, be set at zero. Under these specifications, model (1) can be estimated using the following set of likelihood functions (Cragg):

(2a) $$\Pr(WTP_i = 0 | \mathbf{X}_{1i}, \mathbf{X}_{2i}) = \Phi(-\mathbf{X}_{2i}\gamma/\sigma) + \Phi(\mathbf{X}_{2i}\gamma/\sigma)\Phi(-\mathbf{X}_{1i}\beta);$$

(2b)
$$f(WTP_i \mid \mathbf{X}_{1i}, \mathbf{X}_{2i}, WTP_i > 0) = (2\pi)^{-1/2}\sigma^{-1}\exp\{-(WTP_i - \mathbf{X}_{2i}\gamma)^2/2\sigma^2\}\Phi(\mathbf{X}_{1i}\beta).$$

Here, Φ denotes the standard normal cumulative density function.

Estimation

The bid elicited in the seventh and binding trial is used as the dependent variable. WTP data for all bags were jointly estimated, and fixed effects accounted for differences in cosmetic quality and pesticide treatments. Therefore, the model was estimated using 216 observations. The explanatory variables and parameter estimates can be found in table 6. The first set of explanatory variables (the lefthand side of the table) comprises the matrix $\mathbf{X}_1$ in equation (1a), while the second set (the righthand side of the table) is identified with the matrix $\mathbf{X}_2$ in equation (1b).

The decision to purchase produce from low pesticide input production systems is hypothesized to be influenced by concern about pesticide use in food production and concern about *food* prices. We therefore included the variables *PESTCONC* and *PRCONC* in the first set of variables. The variable *APRICE*, measuring the concern about the price of *apples*, is included in the second set of variables, as it will influence the decision on how much to spend if the reduced pesticide use is preferred. The decision of how much to spend also depends on income (*INCOME*) as well as on the amount of apples consumed in the household (*CONSUMPTION*). To allow for the fact that some consumers might not accept any cosmetically blemished fruit, while others might do so at a lower price, the variable *COSM* is included in both sets (*COSM* = 0 for no cosmetic damage; *COSM* = 1 for cosmetic damage). The amount of pesticide use reduction should also influence the WTP, and so the second set of variables includes the variable *NO NAI* (*NO NAI* = 0 for type B apples; *NO NAI* = 1 for type C apples). In response to the National Research Council's report on pesticides in the diets of infants and children, the FQPA places new emphasis on the protection of infants and children. To see how parents of small children respond to the possibility of avoiding NAI in their product choices, the variable *CHILD* (measuring the presence of children age five and below in the household) was included in both sets of variables. The same holds for the demographic variables of age, education, and sex. The experiment was run in four different groups, and dummies are incorporated in the second set of variables to account for possible differences between groups due to the variation in the sets of revealed prices.

Parameter estimates have the expected signs (table 6). Concern about pesticide use in food production increases the probability of a positive WTP, whereas lower cosmetic quality decreases it. Concern about food prices is not significant in determining the preference for reduced pesticide use, but concern about apple prices reduces conditional WTP. Income has a positive and consumption has a negative influence on the WTP. The magnitude of pesticide use reduction (*NO NAI*) increases WTP significantly. The presence of cosmetic damage reduces the likelihood of a positive WTP and also the conditional WTP. It is interesting to note that the influence of cosmetic damage is more significant on the likelihood of positive WTP than on the magnitude of WTP, measured in both its economical and statistical significance. This is in accord with the findings of previous studies that there is a strong rejection of cosmetically blemished produce.

Table 6. Explanatory Variables and Parameter Estimates

Preference for Reduced Pesticide Use		WTP for Reduced Pesticide Use	
Variable	Parameter	Variable	Parameter
Constant 1	-0.571 (-0.536)	Constant 2	-0.133 (-0.359)
PESTCONC	0.605** (3.694)	Dummy for Group 1	0.224 (1.205)
PRCONC	-0.117 (-0.750)	Dummy for Group 2	0.398* (2.486)
COSM	-0.629* (-2.157)	Dummy for Group 3	0.546** (3.211)
CHILD	-1.178* (-2.447)	*INCOME*	0.014** (5.646)
SEX	-0.100 (-0.242)	*CONSUMPTION*	-0.037* (-2.410)
AGE	-0.018 (-1.231)	*APRICE*	-0.145** (-2.606)
EDUC	0.190 (1.522)	*NO NAI*	0.339** (3.134)
		COSM	-0.151 (-1.134)
		CHILD	0.978** (3.829)
		SEX	0.024 (0.123)
		AGE	0.005 (1.119)
		EDUC	-0.017 (-0.371)
		σ^2	0.563** (12.643)
$2[\ln(L) - \ln(L_0)] = 92.989$			

Notes: Numbers in parentheses are the *t*-values of the parameter estimates. Single and double asterisks (*) denote significance at the 0.05 and 0.01 levels, respectively.

The parameter for the variable *CHILD* is significant in both sets of variables (table 6). Households with small children are less likely to have a positive WTP, but if they do, they are willing to pay more. Since the variable *INCOME* measures household income, the first result might be due to the fact that households with children will have a lower income per person. Although none of the demographic variables are individually significant, jointly they are significant at the 0.1 level. Low *t*-values for some of the variables might be due to low variability in the sample.

Table 7. Explanatory Variables and Elasticity Estimates

Variable	Unconditional Elasticity	Conditional Elasticity
INCOME	1.106**	1.061**
	(4.899)	(5.207)
CONSUMPTION	-0.391*	-0.376*
	(-2.382)	(-2.407)
NO NAI[a]	0.497**	0.322**
	(3.845)	(3.437)
COSM[a]	-0.631	-0.120
	(-1.610)	(-0.819)
CHILD	0.395	0.565**
	(1.134)	(6.811)
SEX[a]	-0.119	-0.003
	(-0.263)	(-0.014)
AGE	0.041	0.354
	(0.130)	(1.123)
EDUC	0.481	-0.190
	(0.739)	(-0.439)

Notes: Numbers in parentheses are the *t*-values of the parameter estimates. Single and double asterisks (*) denote significance at the 0.05 and 0.01 levels, respectively.

[a] Here we report Allen elasticities for discrete variables.

Table 7 reports both the unconditional elasticities and the elasticities conditioned on a bid greater than zero. The elasticities are evaluated at the sample mean of the variables, and are calculated according to the formulas found in the appendix. The *t*-values were obtained using a parametric bootstrap of the parameter estimates. WTP has an income elasticity of approximately unity, and income is highly significant in determining WTP. Unconditional and conditional WTP are inelastic in apple consumption. Removing the whole group of NAI versus only APM increases WTP by about 50%, while cosmetic damage decreases average WTP by 63% and conditional WTP by 12%. The presence of children increases the overall WTP by 40% and conditional WTP by 57%.

While the magnitudes of the elasticities should be interpreted cautiously, given the small size of the sample, estimates suggest clear conclusions about the directions and significance of the variables. There is on average a positive WTP to avoid NAI in apples, but this WTP diminishes if quality deteriorates. The net benefit of restricting use of NAI in apple production will therefore depend on whether production systems can be adjusted in a way that allows preservation of current quality. A second issue of relevance to policy formation is that parents of small children have a higher WTP, both on average and conditionally. This appears to be in accord with the increased protection of infants and children warranted by the Food Quality Protection Act.

Conclusion

This investigation used statistical and econometric procedures to analyze WTP data for a partial reduction of pesticide use on apples. The data obtained in an experimental auction suggest that consumer perceptions of product attributes change if pesticides are removed from production, and this is reflected in WTP changes. While support for a positive WTP for nonuse of pesticides was strong if cosmetic attributes remained the same, this result is weakened considerably if cosmetic quality deteriorates.

New legislation under the FQPA requires that pesticides with a common mode of toxic action are considered as one group, and that risks from exposure to pesticides in this group are considered cumulatively. This risk management rule seems consistent with the risk perceptions expressed by participants in our study. The data show that WTP to avoid a group of pesticides versus WTP to avoid one pesticide from that group can increase significantly when consumers are aware of substitution possibilities. Information provided to study participants that substitute pesticides from the same group are less toxic did not increase WTP for the removal of the more toxic one.

The FQPA limits the legal call for economic consideration in the pesticide registration process by setting absolute risk limits regardless of cost implications—the so-called "risk-cup" of allowed risk. But the choice of filling this risk-cup still requires economic analysis in trading off the risks from different pesticides and exposure modes. To reduce risk most efficiently, it is still necessary to consider pesticide cost effectiveness when making regulatory decisions, and studies focusing on the benefits of pesticide use are still needed. Such analyses cannot be comprehensive if changes on the demand side are ignored. Our research suggests that these demand changes can be significant.

Consumer WTP studies in experimental auction markets are constrained in their sample size due to cost consideration and availability of subjects. Nevertheless, the possibility of controlled information release and direct measurement of participants' reactions enables us to develop a better understanding of consumer choices. The data generated in this experiment allow clear qualitative conclusions about the existence of a positive WTP for restrictions in neuroactive insecticide use and about determinants thereof. More comprehensive market studies would be needed to give quantitative welfare measures that could be incorporated into the economic analysis of insecticide use restrictions.

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Appendix

Normalize by setting $\boldsymbol{\delta} = \gamma/\sigma$. Predicted WTP and elasticities can be calculated as follows. The unconditional expectation of WTP is:

$$E[WTP] = \mathbf{X}_2\gamma\,\Phi(\mathbf{X}_1\beta)\Phi(\mathbf{X}_2\delta) + \sigma\Phi(\mathbf{X}_1\beta)\phi(\mathbf{X}_2\delta),$$

where ϕ is the standard normal probability density function. The conditional expectation of WTP is:

$$E[WTP\,|\,WTP > 0] = \mathbf{X}_2\delta + \sigma\lambda(\mathbf{X}_2\delta),$$

where

$$\lambda(\mathbf{X}_2\delta) = \frac{\phi(\mathbf{X}_2\delta)}{\Phi(\mathbf{X}_2\delta)}.$$

The derivative of the unconditional expectation is:

$$\frac{\partial E[WTP]}{\partial X_j} = \beta_j \phi(\mathbf{X}_1\beta)\left[(\mathbf{X}_2\gamma)\Phi(\mathbf{X}_2\delta) + \sigma\phi(\mathbf{X}_2\delta)\right] + \gamma_j \Phi(\mathbf{X}_1\beta)\Phi(\mathbf{X}_2\delta).$$

The derivative of the conditional expectation is:

$$\frac{\partial E[WTP \mid WTP > 0]}{\partial X_j} = \gamma_j\left[1 - (\mathbf{X}_2\delta)\lambda(\mathbf{X}_2\delta) - \left(\lambda(\mathbf{X}_2\delta)\right)^2\right].$$