Farmer Willingness to Pay for Herbicide Safety Characteristics

by

Nicole N. Owens, Scott M. Swinton, and Eileen O. van Ravenswaay[1]

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[1]The authors are, respectively, economist for the U.S. Environmental Protection Agency, and associate professor and professor in the Department of Agricultural Economics at Michigan State University.

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Abstract

Microeconomic studies often make two assumptions: 1) producers focus on profit maximization, disregarding "external" environmental and health costs; and 2) producers have full information about their production processes and markets. This study examines whether these assumptions are valid for the herbicide use decisions of Michigan corn growers. It further examines corn growers' willingness to pay for reductions in risk associated with the use of herbicide safety characteristics.

The approach used involves a mail survey designed to simulate the market for herbicide formulations described as identical to atrazine except that the "new" herbicide formulations are described as a) not carcinogenic to humans, b) not leachable into groundwater, or c) nontoxic to fish. Respondents were asked a variety of questions about their farms, herbicide use, information sources, and their knowledge and opinions of health and environmental effects of atrazine.

A double-hurdle model is used to estimate demand for the "new" formulations. From this, willingness to pay is estimated. As predicted by theory and indicated by previous studies, willingness to pay for risk reductions associated with each of the three safety attributes was positive. Results indicate that mean willingness to pay for source reduction in leaching risk from atrazine is $4.40 per acre for 40 acres and is $4.92 per acre for the carcinogenicity risks. While the average respondent would not demand 40 acres of source reduction in fish toxicity risk from atrazine, mean willingness to pay for 30 acres is $3.92 per acre. For the non-leaching formulation, this result indicates the average respondent would pay a premium of $4.40 cents per acre to purchase 40 acres of an atrazine alternative proven to be non-leaching. As atrazine is typically applied at a cost of $3.00 per acre, these premiums are significant.

The range of willingness to pay estimates for the three aspects of health and environmental quality examined by this research suggest that farmers are more concerned about on-farm health and environmental effects than about off-farm effects. For each of the quantities examined here, per acre willingness to pay for reductions in fish toxicity risks was less than that associated with reductions in leaching and carcinogenicity risks. Cancer and leaching are generally on-farm effects, while harmful effects to fish tend to occur "downstream." The mean levels of adoption for the three attributes also confirm this. Over 40 percent of respondents indicated they would use some of the non-leaching and non-carcinogenic attributes, while only 25 percent indicated similar intentions for the fish-safe attribute.

The results for the non-leaching attribute allowed testing of the hypothesis that willingness to pay increases with knowledge of the potential of atrazine to leach. The empirical results suggest that average willingness to pay for reductions in the leaching risk from atrazine would increase by approximately 9 percent if all farmers were fully informed of the leaching potential of atrazine.

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Introduction

There is little doubt that herbicides are an important input in the production of many agricultural commodities. Herbicides can significantly reduce yield loss without the soil erosion sometimes caused by tillage. However, certain herbicides can cause adverse effects to both human health and the environment, including contamination of ground and surface water, as well as chronic and acute health effects to humans fish, and wildlife. Prior research has shown that farmers are concerned about pesticide risks to human health and environmental quality (Higley and Wintersteen; Beach and Carlson; Mullen, Norton, and Reaves). Farmers' willingness to pay (WTP) for reduced risk from pesticides has the potential to be a valuable asset in the design of policies that reduce the public's risks from pesticides. Reliable estimates of farmers' WTP for reduced pesticide risk are fundamental. However, existing estimates of WTP suffer from vagueness, potential bias, and/or omission of relevant attributes. This study attempts to improve on prior estimates of WTP for reduced pesticide risk through analysis of data from a carefully designed contingent valuation (CV) survey.

Conceptual Model and Approach

The conceptual model posits that farmers care about health (H), environmental quality (V), and consumption goods (Z), seeking to maximize utility, subject to a budget constraint and minimum acceptable levels of H and V. Herbicides (h) control weeds (w) so that yield damage (d(w)) is reduced (d'(w) > 0; d"(w) < 0; w'(h) < 0). However, herbicide use may also pose risks to human health and environmental quality (H'(h) $\leq$ 0; V'(h) $\leq$ 0):

$$Max\ \ U(Z, V, H) \ = \ p_y y(x)(1 - d(w(h))) - r_x x - r_h h$$

Subject to:

$$p_y y - r_x x - r_h h \geq p_z Z$$
$$V(h) > V_{\min}$$
$$H(h, Z) > H_{\min}$$

Where Z=consumption goods, p_i=output and consumption good prices, y=crop yield, x=crop increasing inputs ($y'(x) > 0$; $y''(x) < 0$), and r_x=input prices. From this model, an input demand function can be derived revealing non-negative WTP for an herbicide that is safer in terms of its effect on human health and/or the environment.

The derived demand model highlights the elements that should be included in any empirical estimate of WTP for herbicide safety. In addition to input and output prices, these elements include pest-related factors as weed damage and herbicide efficacy, and also those factors that affect the farmer's marginal utility of health, the environment, and income. The agricultural technology adoption literature lists some of the categories of variables that condition these factors, including farm characteristics, household (or personal) characteristics, technology characteristics, and institutional environment (Feder, Just, and Zilberman; Owens, Swinton, and van Ravenswaay, 1997b). For the adoption of environmental innovations, farming orientation is also an important explanatory factor (Pampel and van Es; Taylor and Miller; McNamara, Wetzstein, and Douce; D'Souza, Cyphers, and Phipps).

This constrained utility model provides a conceptual framework that was absent from the previous CV studies of pesticide risks reduction studies by Higley and Wintersteen (HW) and Mullen, Norton and Reaves (MNR). The HW study, a survey of corn growers in four Midwestern states, focused on the marginal utility of health and environmental quality variables omitting the yield loss and pesticide efficacy variables, the budget constraint, and most of the conditioning variables. The MNR study surveyed a random sample U.S. consumers. It followed the HW methodology on health and environmental quality variables, but added a budget constraint implicit in the respondent's monthly grocery bill. Again, no conditioning variables are reported.

A major problem with both the HW and the MNR studies was their reliance on a vague "high-medium-low" scaling of perceived risks. Farmers and consumers are asked for their WTP to reduce these perceived risk levels to human health (acute and chronic), water (ground and surface), and non-target species (aquatic, avian, mammalian, and arthropod). Yet the non-expert survey respondents are provided very little information with which to assess risk levels. As a result, they are likely to vary widely in the degree of risks perceived, implying that their expressions of WTP are not for a uniform level of risk reduction. This vagueness in defining the contingent market setting seriously undermines the credibility of resulting estimates, though no clear direction of bias can be discerned *a priori*.

Beach and Carlson's hedonic analysis of herbicide prices arises from a multi-attribute utility function similar to the one presented above. Their model clearly demonstrates that there exists farmer willingness to pay for user safety and water quality in herbicide purchases. However, the amount of WTP is subject to criticism at two levels. First, farmer WTP may exist for other, unmeasured environmental and human health attributes, such as safety of non-target species and avoidance of indirect human health risks. If so, their model gives, at best, a lower bound estimate of WTP for pesticide risk reduction. Second, relevant explanatory attributes may have been omitted from the hedonic pricing model. One example is the length of the period during which a herbicide is effective in post-emergence application, an attribute which had been a leading sales pitch for several current herbicides. The potential bias from such an omission is indeterminate, depending upon the correlation between the omitted variable(s) and those that were included.

Empirical analysis

A mail survey of 2000 Michigan corn growers was used to gather the data necessary to estimate demand and willingness to pay for herbicide safety characteristics. The survey was designed to simulate the market for three herbicide formulations described as identical to atrazine, except that the new herbicide formulations are described as a) not carcinogenic to humans, b) not leachable into groundwater, or c) nontoxic to fish. Atrazine was chosen because of its familiarity to farmers; over 65 percent of U.S. corn acreage is treated with atrazine (Ribaudo and Bouzaher). Because of this familiarity with atrazine and its characteristics, it was felt that respondents would be able to critically evaluate the choice between the hypothetical formulation and regular atrazine. This obviated the need to offer a comprehensive list of herbicide attributes, since the only one property at a time differed from a product well-known to respondents. Each respondent was asked to consider use of regular atrazine separately against each of the three new formulations. Thus, each farmer made three pair-wise comparisons.

Farmers were offered the option of purchasing these new formulations in an accept-reject format at specified prices and market conditions. In order to be certain of the reference price from which respondents were working and because regular atrazine is the most likely substitute for the new formulations, the price of regular atrazine was specified as $3.00, $3.75, or $4.50 per pound. The price of the new formulations were equal to, 50 cents, $1, $3, or $5 more than regular atrazine. The prices were assigned so that each respondent faced a choice on only one price pair. Respondents were asked whether they would use, in 1996, the new atrazine at the stated prices and, if so, on how many acres this formulation would be applied.[1]

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[1]Specifically, the non-leaching purchase scenario was given as follows:

Now we would like to ask you some questions about herbicide choices you might make next year. In answering these questions, please suppose that next spring is the same as this year in terms of weather, weed conditions, weed control cost, and other things that affect your herbicide choices. Please also suppose that atrazine is available for $3.00 per pound.

Suppose a chemical company made a new formulation of atrazine that was identical to regular atrazine, except the new formulation **does not leach**. This new formulation is available for $4.00 per pound. Next year, would you purchase the new formulation and make it a significant part of your herbicide program? (Please circle number of your answer.)

1. YES
On how many acres would you use the new formulation?
(Please write in number of acres.)
_____ SOIL APPLIED _____ FOLIAR APPLIED
2. NO

Respondents also answered a set of background questions upon which to condition their responses about WTP. These questions concerned farm and personal characteristics, as well as questions concerning their awareness and attitudes toward scientific assessments of the health and environmental risks associated with atrazine use. The questions included in the survey were designed to gather information on or act as proxies for variables proving to be important in the theoretical model and adoption literature. For example, questions concerning well water-contamination were designed to capture environmental quality. Questions concerning respondents' awareness and beliefs concerning the health and environmental effects of atrazine were designed to capture perceptions about health and environmental quality.

The 1995 midsummer survey had an overall response rate of 54 percent, including 656 respondents (35 percent) who both used herbicides and grew corn. The sound response rate contrasts with the 22 percent rate of HW and the 17 percent rate of MNR, both of which raise concerns about potential response bias if respondents felt more strongly about health and environmental quality than non-respondents.

Estimating Willingness to Pay

Total willingness to pay for reductions in risk associated with use of the safety characteristics is the area to the left of the Marshallian demand function for the given attribute from zero to the quantity of interest (Owens; Willig; Freeman). In order to estimate WTP, estimating a demand curve for each non-marketed attribute is necessary. One plausible description of farmers' purchase of the alternative formulations (and therefore the safety attributes and risk reduction) models two separate decisions. First, the farmer decides whether or not to use any of the safer pesticide and hence the safety attribute in question (hereafter referred to as the adoption decision). Second, if adopting, the farmer must decide how much of the safer pesticide and hence the attribute to use (the consumption decision). Accordingly, it is important to know the factors which determine both adoption and consumption.

Cragg's double-hurdle model can be used to explicitly model this two-stage decision making process. The presentation of the Cragg model borrows heavily from Bockstael et al. The double hurdle takes the form:

$$y_i = 0 \quad if\ w_i^* \leq 0$$
$$y_i = 1 \quad if\ w_i^* > 0$$
$$w_i^* = B_2 z_{2i} + v_i.$$

Conditional on $w_i^* > 0$,

$$r_i = B_1 z_{1i} + u_i \quad if\ B_1 z_{1i} + u_i > 0$$
$$r_i = 0 \quad if\ B_1 z_{1i} + u_i \leq 0$$

Here, ρ is the quantity of the attribute and z_{1i} and z_{2i} are vectors of individual characteristics of the *i*th individual, v_i is $N(0,\sigma^2_v)$, and u_i is $N(0, \sigma^2_u)$. The variables included in the B_1 and B_2 vectors are those determined to be important in the theoretical model discussed earlier. The individual farmer may indicate he would not participate in the market for one of two reasons; he may have chosen not to participate because of factors in either the z_1 or z_2 vector. The log likelihood is separable in parameters, therefore it can be maximized in two stages. The first stage, the adoption decision, is estimated using a probit. The second stage, the consumption decision, is estimated using a truncated regression.

In the Cragg model, the demand function is given by:

$$E(x_i) = \Phi(\hat{B}_2 z_{2i})(\hat{B}_1 z_{1i} + s_u(f(\hat{B}_1 z_{1i} / s_u) / \Phi(\hat{B}_1 z_{1i} / s_u)))$$

Where Φ and ϕ are the cumulative distribution function and the probability density function of the standard normal.

By construction, the only difference between regular atrazine and the new formulations described in the survey is the safety characteristic. Therefore, the price difference between regular atrazine and new atrazine can be considered the price of the safety characteristic in question. As an illustration, consider the non-leaching formulation. The only difference between regular atrazine and the hypothetical, non-leaching formulation is the new formulation's "non-leachingness." If the price of regular atrazine was given as $3.00 per acre and the price of the non-leaching formulation as $6.00 per acre, the price of "having no leaching" or of "non-leachingness" is $3.00 per acre.[2] Thus, one can also estimate the demand function for the safety characteristic.

Results

The variables used in the double-hurdle demand estimations are defined in Table 1. Tables 2 through 4 present the double-hurdle regression results. All results were estimated using LIMDEP Version 7.0 (Greene, 1995).

It was expected that the price of the safety characteristic (PRICEDIFFERENCE) would be of paramount importance in the double-hurdle demand estimation. For all three formulations, the estimated coefficient on this variable is negative and highly significant in the adoption decision. The coefficient tends to be less significant in the consumption decisions. For a detailed discussion of the double hurdle results, see Owens, Swinton and van Ravenswaay (1997b).

Three measures of WTP were calculated for each of the safety attributes; total, mean, and marginal WTP. These measures were calculated using the mean values of the dependent variables from the

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[2]Atrazine is typically applied at a rate of 1 pound per acre. Therefore, price can be in terms of either dollars per pound or dollars per acre.

double-hurdle demand equations for the safety characteristics.[3] The result is the average respondent's demand. The area under the demand curve for different prices and quantities can then be calculated. This measure of WTP is the average respondent's total WTP for source reduction in risks from atrazine for 1996. Mean WTP per acre of risk reduction for 1996 can then be calculated by dividing by the appropriate quantity.[4] The results of the WTP estimation are presented in Tables 5 through 7.

As expected, total WTP increases as quantity increases, while mean and marginal WTP decreases for all three safety characteristics. The average respondent's mean WTP per acre for 10 acres of reduction in leaching risks from atrazine is $7.77. This decreases to $4.40 for 40 acres of risk reduction. Results for the non-carcinogenic attribute, indicate that the average respondent's mean WTP per acre of reduction in carcinogenicity risks from atrazine ranges from $8.47 for 10 acres of risk reduction to $4.92 for 40 acres of risk reduction. Compared with a baseline price for atrazine of $3.00 per acre, these figures represent an average WTP of more than 100 percent more for these two safety attributes.

Cancer is a catastrophic and, in many cases, fatal health effect. Therefore one might expect that WTP for reductions in carcinogenicity risks be even greater than those for reductions in leaching risks than indicated. However, by "purchasing" the non-leaching attribute, a farmer reduces the amount of atrazine that leaches into groundwater. If this water is then used for household purposes, the farmer also reduces his and his family's exposure to the chemical (the non-leaching attribute is one example of one that is safer

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[3]For illustration purposes, consider the non-leaching characteristic. The vector of coefficients from the adoption decision was multiplied by a vector containing the mean value of each variable (excluding price, the coefficient on price is multiplied by p, the variable of integration). The result, $[B_{2\text{-price}}*z_{2\text{-price}} + B_{price}*p]$ is substituted for B_2z_2 in the calculation of the Cragg demand function. A similar procedure is followed for the consumption decision (the B_1 component).

[4]When calculating WTP in this manner, one question that may arises deals with the handling of binary variables. As an example, what does it mean to have CHILDREN=.5? One solution is to calculate weighted WTP. That is, to calculate the WTP for each possible combination of binary variables and multiply by the frequency with which each occurs. However, due to the number of binary variables in the model (12 in the leaching model) and the resulting possible combinations of binary variables (almost 275 out of a possible 2^{12} or 4096), and the results of a consistency check discussed later, it was felt that this calculation would not lead to substantially different results.

to both humans and the environment). As exposure to atrazine may cause cancer, presumably, the farmer may also reduce risk of cancer by reducing groundwater contamination.

Both total and mean WTP associated with the fish-safe characteristic are less than that of either the non-leaching or non-carcinogenic attributes. This result was expected for two reasons. First, one would expect attributes that protect human health be valued more than other attributes; the non-leaching and non-carcinogenic attributes protect human health, while the fish-safe attribute protects fish. Second, as detailed in the survey, atrazine is only *slightly* toxic to fish, yet it has a *high probability* of leaching and is classified as a *possible* human carcinogen. The average respondent's mean WTP for reduction in toxicity risks to fish ranges from $6.81 for 10 acres to $3.05 for 30 acres. At positive prices, 40 acres of this risk reduction would not be demanded.

As a check for consistency, the WTP calculations were computed using only price. When performing the calculations, price is the important variable. As the survey sample was random and the prices provided in the survey were randomly assigned across the sample, the estimates of WTP calculated using just price (double-hurdle model was calculated using price and a constant as the only variables) should be similar to those obtained conditioned on other variables. In all equations, the estimated coefficient on the price variables are all negative and highly significant.

The WTP estimates calculated using only price are similar to those estimated with the full set of conditioning variables (fifth columns of Tables 5 through 7). From Table 5, mean WTP per acre for 40 acres of reduction in risks associated with leaching is $4.40. Mean WTP per acre for 40 acres calculated using only price is $4.63. Similarly, mean WTP per acre for 10 acres of reduction in risks associated with cancer is $8.47, calculated using only price, this value is $8.81. The results for 20, 30 and 40 acres of non-carcinogenicity are slightly less similar as are the results for fish-safety. Mean WTP per acre for 30 acres of reduction in fish toxicity risk is $3.94 using all variables and $4.92 using only price.

It was hypothesized that as the respondent farmer's knowledge of and agreement with the health and environmental effects (perhaps indicating the farmer's perceived risk) of atrazine increase, WTP should increase. The double-hurdle results from the non-carcinogenic and fish-safe formulations do not provide evidence that adoption and/or use and therefore WTP may increase with an increase in knowledge or risk perceptions. Indeed, the double hurdle results for the non-carcinogenic formulation indicate that knowledge that atrazine has been classified as a possible human carcinogen is insignificant, although this result may be due to the phrasing of the question. Respondents were not asked to consider their own risk of cancer, but rather whether they agreed or disagreed with the general statement that atrazine has been classified as a possible human carcinogen.

The double-hurdle results from the non-leaching formulation do provide results allowing this hypothesis to be tested. This hypothesis was tested by calculating WTP associated with the non-leaching attribute if all farmers agreed that atrazine has a high probability of leaching or believe atrazine is more likely to leach than indicated. Results from this calculation indicate that mean WTP for 10 acres of reduction in leaching risk from atrazine increases from $7.77 to $8.45 if all farmers were aware that atrazine has a high leaching potential. This represents an increase of 9 percent. As only 33 percent of respondents felt that atrazine has a high probability of leaching or is more likely than indicated, this result provides evidence that a campaign designed to provide information and thereby change perceptions could be highly influential.

Conclusions

This study presented a contingent valuation analysis of corn producers' WTP for reduced health and environmental risks from herbicides. The CV approach followed employs an accept-reject approach to purchasing a hypothetical herbicide formulation that differs from a known product in only one attribute. In so doing, the approach avoids the strategic and omitted variable biases that may have afflicted previous estimates of WTP for reduced pesticide risk. Specifically, this study examined WTP for reductions in source risks associated with leaching potential, carcinogenicity, and fish toxicity relative to the herbicide atrazine. Mean willingness to pay for 10 to 40 acres of reduction in risks associated with the non-carcinogenic atrazine attribute ranged from $4.92 to $8.47 per acre, while mean willingness to pay associated with the non-leaching attribute was between $4.40 and $7.77 per acre. Willingness to pay for fish-safety was somewhat lower. Given that atrazine may be purchased for approximately $3.00 per pound and is generally used at a rate of 1 pound per acre, these amounts are large in a relative sense. For example, willingness to pay for reductions in the leaching risk of atrazine ranges from 259 to 146 percent of the price of atrazine.

The range of willingness to pay estimates for the three aspects of health and environmental quality examined by this research suggest that farmers are more concerned about on-farm health and environmental effects than about off-farm effects. For each of the quantities examined here, per acre willingness to pay for reductions in fish toxicity risks was less than that associated with reductions in leaching and carcinogenicity risks. Cancer and leaching are generally on-farm effects, while harmful effects to fish tend to occur “downstream.” The mean levels of adoption for the three attributes also confirm this.

These results also provide some evidence that willingness to pay increases with awareness and concern about environmental risks. Another future research challenge is to design variables that more fully capture farmers’ knowledge of the health and environmental risks of agricultural chemicals. With this information, more complete measures of the benefits of changing perceptions and therefore of information campaigns would be possible.

Table 1 - Variables Included in Model

Variable	Meaning, Units	Variable	Meaning, Units
	DEPENDENT		
ADOPTL	Use of non-leaching formulation, (0,1)	ACRES APPLIEDC	Area on which no-cancer formulation would be used, Acres
ACRES APPLIEDL	Area on which non-leaching formulation would be used, Acres	ADOPTF	Use of fish safe formulation, (0,1)
ADOPTC	Use of no-cancer formulation, (0,1)	ACRES APPLIEDF	Area on which fish-safe formulation would be used, (Acres)
	INDEPENDENT		
	FARM ORIENTATION		
HRSWORK	Time worked off farm, Hours		
	FARM CHARACTERISTICS		
INCOME	Household adjusted gross income, 1000sof dollars	IRRIGATE	Proportion of corn fields that are irrigated, %
LIVESTOCK	Proportion of income from livestock, %	NOTILL	Proportion of corn acres on which no till practiced, %
ACRESCORN	Area of corn farmed, Acres	WEEDPRESSURE	More than slight weed pressure, (0,1)
ATRAZINE95	Used some form of atrazine in 1995, (0,1)	UNTREATEDWATER	Primary source of drinking water is untreated well water, (0,1)
RESIST	Had weeds resistant to atrazine, (0,1)	USENEAR	More than ½ of neighboring farms use atrazine, (0,1)
	PERSONAL CHARACTERISTICS		
CHILDREN	Have children under age 18, (0,1)	LABEL	Relies on chemical label for information,
EXPERIENCE	Years of farming experience, Years	MAGAZINE	Relies on trade magazine for information, (0,1)
COLLEGE	Education past high school, (0,1)	MSDS	Relies on material safety data sheets for
CONSULTANT	Relies on consultant for information, (0,1)	MSU	Relies on MSU extension for information, (0,1)
DEALER	Relies on dealer for information, (0,1)	PAPER	Relies on newspaper for information, (0,1)
FARMER	Relies on other farmers for information, (0,1)		
	RISK PERCEPTIONS		
CARCIN	Knew atrazine classified as possible human carcinogen, (0,1)	FISHTOX	Familiar with fact that atrazine slightly toxic to fish, (0,1)
GOVREG	Most important reason to use no cancer formulation is risk of future regulation, (0,1)	LEACH	Agrees with or feel scientific opinion about leaching understated, (0,1)
FISH	Fish within 1/4 miles of corn fields, (0,1)	CONTAMINATED	Well water contaminated from agricultural chemicals, (0,1)
FISHM	Feels scientific opinion concerning fish toxicity understated, (0,1)		
	PRICE		
PRICEDIFFERENCE	Price difference between new and conventional formulations, Dollars		

Table 2 - Double Hurdle Regression Results for Non-Leaching Formulation

Adoption of non-leaching atrazine formulation (Probit, N=301)		
Variable	Estimate	P-Value
CONSTANT	0.43E-1	0.91
INCOME	0.31E-5	0.31
ACRESCORN	-0.11E-2	0.01
ATRAZINE95	0.44	0.05
RESIST	0.39	0.02
WEED PRESSURE	-0.19	0.33
USENEAR	0.57	0.00
EXPERIENCE	-0.11E-1	0.12
DEALER	-0.28	0.09
LEACH	0.30	0.06
CONTAMINATED	-0.71	0.24
PRICEDIFFERENCE	-0.25	0.00
Consumption of non-leaching atrazine formulation (Truncated N=147)		
Variable	Estimate	P-Value
CONSTANT	-274.21	0.00
INCOME	1.30	0.01
LIVESTOCK	-0.65	0.22
ACRESCORN	0.81	0.00
NOTILL	0.96	0.01
USENEAR	102.92	0.02
CHILDREN	17.76	0.54
COLLEGE	-103.18	0.00
DEALER	66.73	0.04
FARMER	-58.70	0.13
CONTAMINATED	42.06	0.63
PRICEDIFFERENCE	-6.39	0.55
σ	102.61	

Summary Statistics	**Adoption** LRI=.18 Adoption prediction rate=.694 Non-adoption prediction rate=.669	**Consumption** -Log likelihood=765

Table 3 - Double Hurdle Regression Results for Non-Carcinogenic Formulation

Adoption of no-cancer atrazine formulation (Probit, N=352)		
Variable	Estimate	P-Value
CONSTANT	-0.19	0.51
INCOME	0.38	0.90
ACRESCORN	-0.33E-3	0.19
ATRAZINE95	0.41	0.04
IRRIGATE	-0. 1	0.05
USENEAR	0.62	0.00
EXPERIENCE	-0.98E-2	0.12
PAPER	0.25	0.25
MSU	0.28	0.06
MAGAZINE	-0.25	0.12
PRICEDIFFERENCE	-0.21	0.00
Consumption of no-cancer atrazine formulation (Truncated N=163)		
Variable	Estimate	P-Value
CONSTANT	-285.96	0.00
ACRESCORN	0.86	0.00
ATRAZINE95	58.55	0.22
RESIST	32.39	0.12
USENEAR	64.30	0.04
UNTREATED WATER	52.34	0.18
LIVESTOCK	-0.34	0.33
COLLEGE	-58.31	0.01
DEALER	32.52	0.16
LABEL	45.43	0.12
MSDS	-30.33	0.24
CARCIN	-24.11	0.25
CONTAMINATED	81.24	0.39
HEALTH	49.28	0.06
PRICEDIFFERENCE	-9.11	0.30
σ	85.90	

Summary Statistics	**Adoption** LRI=.14 Adoption prediction rate=.714 Non-adoption prediction rate=.693	**Consumption** -Log likelihood=849

Table 4 - Double Hurdle Regression Results for Fish-Safe Formulation

Adoption of fish-safe atrazine formulation (Probit, N=313)

Variable	Estimate	P-Value
CONSTANT	-0.35	0.29
HRSWORK	0.73E-2	0.04
INCOME	-0.13E-5	0.66
IRRIGATE	-0.64E-2	0.26
RESIST	0.30	0.06
USENEAR	0.39	0.03
EXPERIENCE	-0.23E-1	0.00
PAPER	0.28	0.23
FISH	0.47	0.38
FISHM	0.38	0.29
FISHTOX	0.17	0.32
PRICEDIFFERENCE	-0.17	0.00

Consumption of no-cancer atrazine formulation (Truncated N=90)

Variable	Estimate	P-Value
CONSTANT	-85.07	0.27
HRSOWRK	0.65	0.34
LIVESTOCK	-1.92	0.01
ACRESCORN	0.52	0.00
IERIGATE	4.67	0.00
USENEAR	49.48	0.27
CHILDREN	58.60	0.10
COLLEGE	-111.41	0.00
CONSULTANT	-65.14	0.13
FARMER	-97.56	0.04
LABEL	71.80	0.09
SALESMAN	84.92	0.03
FISHM	-53.69	0.36
PRICEDIFFERENCE	-16.90	0.15
σ	95.51	

Summary Statistics	**Adoption**	**Consumption**
	LRI=.12 Adoption prediction rate=.278 Non-adoption prediction rate=.924	-Log likelihood=484

Table 5 - Average Respondent's Estimated Total, Mean and Marginal Willingness to Pay Associated with Non-Leaching Characteristic

Pounds	Total willingness to pay ($)	Mean willingness to pay ($/acre)	Marginal willingness to pay ($)	Mean willingness to pay calculated using only price ($/acre)
10	$77.74	$7.77	$5.78	$7.42
20	$125.42	$6.27	$3.88	$6.17
30	$157.10	$5.24	$2.49	$5.31
40	$175.80	$4.40	$1.26	$4.63

Table 6 - Average Respondent's Estimated Total, Mean and Marginal Willingness to Pay Associated with Non-Carcinogenic Characteristic

Pounds	Total willingness to pay ($)	Mean willingness to pay ($/acre)	Marginal willingness to pay ($)	Mean willingness to pay calculated using only price ($/acre)
10	$84.68	$8.47	$6.29	$8.81
20	$136.96	$6.85	$4.32	$7.53
30	$173.05	$5.77	$2.95	$6.66
40	$196.78	$4.92	$1.82	$5.99

Table 7 - Average Respondent's Estimated Total, Mean, and Marginal Willingness to Pay Associated with Fish-Safe Characteristic

Pounds	Total willingness to pay ($)	Mean willingness to pay ($/acre)	Marginal willingness to pay ($)	Mean willingness to pay calculated using only price ($/acre)
10	$68.13	$6.81	$4.46	$7.34
20	$102.17	$5.11	$2.32	$5.91
30	$118.17	$3.94	$0.93	$4.92

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