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FARMER WILLINGNESS TO PAY FOR HERBICIDE SAFETY CHARACTERISTICS

By

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ABSTRACT

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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.

Descriptive statistics indicate that many farmers do consider health and environmental factors when making herbicide choices and are willing to purchase safer herbicides, even at a price premium. However, many are unaware of or disagree with scientific findings on herbicide risks.

A double-hurdle model is used to estimate demand for the "new" formulations. The probit results (the first stage) indicate that price and farm size are important factors in

the decision to use the "new" formulations. Sources relied on for herbicide information also proved to be influential. Awareness of the need for safer herbicides (as measured by familiarity with the health and environmental effects of atrazine) proved to be important in the adoption of the non-leaching and fish-safe formulations. The truncated regression results (the second stage) indicate that price is of a lesser concern in deciding how much of the alternative to use once the decision to use has been made. Sources of information also proved influential in determining intensity of use. Empirical results indicate that farmers are willing to pay for elimination of perceived atrazine risks on 30 acres of corn an average of $5.24 per acre for leaching risks, $5.77 per acre for carcinogenicity risks, and $3.94 per acre for fish toxicity risks. Given that atrazine is available for approximately $3.00 per pound and generally applied at a rate of 1 pound per acre, the magnitude of these figures is significant.

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Chapter 1

INTRODUCTION

Both the general public and agricultural policy makers have become increasingly concerned about the health and environmental effects of pesticides. It has long been known that use of agricultural pesticides is beneficial in that both the quantity and quality of agricultural products is increased by reducing damage from pests. However, much attention has recently been placed on the adverse health and environmental risks these chemicals may pose. Exposure to pesticides has been linked to numerous health problems such as lymphoma, reproductive tract cancer, Hodgkins' disease, leukemia, and infertility (Blair et al., 1985; Colborn et al., 1993; Blair, Francis, and Lynch, 1997). It has been estimated that 446,000 rural domestic wells contain levels of pesticides above Maximum Contaminant Levels set by the Environmental Protection Agency (EPA, 1990). In addition, agricultural pesticide use has been shown to adversely affect various forms of wildlife including fish, alligators, and birds (Pimentel et al., 1992; Hileman, 1994). It has been estimated that pesticide runoff into aquatic environments kills 6-14 million fish annually (Pimentel et al., 1992).

In response to these concerns, a variety regulations have been adopted. The Federal Insecticide, Fungicide, and Rodenticide Act directs the Environmental Protection

Agency (EPA) to determine whether use of a pesticides results in greater benefits than risks. If so, proper methods of use, including the crops on which the pesticide can be applied, must also be determined. In addition, the EPA may initiate Special Review of potentially harmful chemicals. For example, in 1994 a Special Review of three triazine herbicides, including atrazine, was initiated due to concern that residues on food and in drinking water may increase the risk of cancer as well as out of concern for those who handle and apply these chemicals. Not all pesticide regulations are federal; many individual states have banned the use of certain pesticides in particularly vulnerable areas.

In order to develop policies that more effectively address these health and environmental concerns, a more complete understanding of the pesticide user, the *farmer,* is needed. Policy makers need to understand more about how farmers make pesticide use decisions. Many of the above regulations are based on the idea that farmers are not concerned about health and environmental quality, yet existing research clearly shows this assumption to be false (Higley and Wintersteen, 1992; Beach and Carlson, 1993). However, more complete information is needed on farmer willingness to self regulate out of concern for their own heath, the health of others, and/or the environment.

This research investigates the factors motivating farmers' use of safer pesticides and estimates their willingness to pay for source reduction in risks associated with herbicide safety characteristics. Three safety characteristics are examined: non-leaching, non-carcinogenic, and fish safe. A variety of farm and personal characteristics as well as knowledge of the health and environmental effects of herbicides were hypothesized to influence demand for the three characteristics. Using a two-stage demand model, these hypotheses are tested. Farmer willingness to pay associated with each characteristic is estimated. In addition, this research also investigates the hypothesis that knowledge of the health and environmental effects of pesticides is an important determinant of willingness to pay.

The data used in this study comes from a mail survey conducted in Michigan in the summer of 1995. The survey offered Michigan corn farmers the option of purchasing, for use in 1996, regular atrazine or a hypothetical alternative atrazine formulation. Three hypothetical formulations were examined: one described as non-leaching, another as non-carcinogenic, and the third as non-toxic to fish. Respondents were then asked whether they would use each of the hypothetical formulations and, if so, on how many acres they would apply the new formulation. Respondents also answered questions about 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 and about the sources of information used to learn about these risks.

The data from the survey were used to evaluate demand for the new formulations in two stages. The factors influencing the decision to adopt as well as the factors influencing intensity of use of the each of the hypothetical formulations were examined. The parameters from the demand equations were used to estimate farmer willingness to pay. In addition, the effect of increased information on willingness to pay is also estimated.

The remainder of the dissertation is organized in a three article format. That is, each of the subsequent chapters, with the exception of the conclusion chapter, stands on its own. Chapter 2, the first article, presents a detailed description of the survey methods used to measure farmer demand and willingness to pay for herbicide safety characteristics. It then presents descriptive statistics of the survey results. Chapter 3, the second article, presents the two-stage model of demand used to investigate the factors influencing adoption and intensity of use. The results from the demand equation estimation are also discussed. Chapter 4, the third and final article, presents the theoretical framework used to make inferences about farmer willingness to pay for reductions in risk associated with herbicide safety characteristics. It also discusses how demand equations can be used to estimate willingness to pay. Finally, it presents the willingness to pay estimates. The overall conclusions and policy implications are presented in Chapter 5.

Chapter 2

FARMER DEMAND FOR SAFER CORN HERBICIDES: SURVEY METHODS AND DESCRIPTIVE RESULTS[1]

Introduction

Herbicide use is beneficial but also risky. While use of herbicides can reduce yield loss significantly and, in minimum or no-till farming, may also reduce soil erosion, herbicide use may also harm human health and the environment. Farm worker exposure to herbicides has been associated with both chronic and acute heath effects such as non-Hodgkin's lymphoma and leukemia (Blair and White, 1985; Hoar et al., 1986; Wigle et al., 1990). At times, herbicides in surface and groundwater drinking water supplies exceed threshold levels specific under the Safe Drinking Water Act (Ribaudo, 1993). Adverse effects on the environment also include fishery losses and a variety of effects on other species of wildlife such as birds and alligators (Hileman, 1994).

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) was adopted because of public concern that unregulated markets were not adequately balancing the

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[1]This chapter appeared earlier as: Owens, N., S. Swinton, and E. van Ravenswaay. "Farmer Demand for Safer Corn Herbicides: Survey Methods and Descriptive Results." Michigan Agricultural Experiment Station, Research Report No. 547, Michigan State University, East Lansing, MI. 1997.

risks of pesticide use against the benefits. As amended in 1988, FIFRA directs the U.S. Environmental Protection Agency (EPA) to determine whether the use of a pesticide (including herbicides) results in greater benefits than risks and, if so, to establish proper methods of use. Commercial applicators must be licensed and trained in these methods. Product labels must indicate proper methods of use and disposal as well as precautions needed to prevent harm to humans, animals and the environment. In addition, some states have put further restrictions on pesticide use. For example, Wisconsin has imposed regional bans on herbicide use, while Michigan and Iowa have levied input taxes on pesticides.

These approaches to government regulation reflect two assumptions about how risks and benefits are balanced in unregulated pesticide markets. One assumption is that in unregulated markets pesticide sellers will not provide pesticide users adequate information about the risks they may suffer from improper use of pesticides. Thus, one goal of regulation is to ensure that information on risk avoidance is provided. The second assumption is that many of the risks are external to the pesticide user (e.g., risks to surface and groundwater, wildlife and farm labor), and thus not accounted for by users in unregulated markets. Thus, a second goal of regulation is to internalize the externality.

A small body of published information has challenged the assumption that pesticide users ignore external impacts (Beach and Carlson, 1993; Higley and Wintersteen, 1992; Mullen, Norton, and Reaves, 1997). These studies provide evidence that farmers are concerned about environmental and health effects of pesticides and are willing to pay to reduce these effects. If true, there may exist opportunities to reduce herbicide risks through voluntary measures.

The dearth of information on private producer willingness to pay for herbicide safety has two consequences.[2] First, it deters accurate measurement of potential reductions in herbicide use that could be obtained through herbicide safety education programs. Second, it inhibits the development of a market for herbicide safety. Such markets have been developed for consumer products by creating government-approved labeling schemes that allows purchasers to compare safety or quality attributes across product brands. Currently there is no *comparative* safety information on herbicide labels.[3] However, one could be established by rating herbicides in terms of health, environmental, and weed control effects. Purchasers would then have the information needed to make tradeoffs between these safety attributes and price.

The purpose of this research is to develop and demonstrate methods for estimating the demand for herbicide safety and the potential benefits of safety information (e.g., on labels). Corn herbicides were chosen as the focus of the study as corn accounts for more herbicide use than any other U.S. crop (USDA, 1993). A major part of the research was developing and implementing methods for collecting the data needed to estimate farmers' demand for safer herbicides. The purpose of this report is to describe the development of

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[2]The term "herbicide safety" will be used to refer to both the health and environmental effects of herbicides.

[3]Safety information is currently provided on labels, but it is not comparative information. For example, two different products may pose hazards to fish or birds, but one product may be more hazardous than the other. While several schemes have been developed to allow comparisons of hazards, none appear on herbicide labels.

the data collection instrument, explain how it was implemented in the field and present descriptive statistics on the data obtained. Future reports will utilize this data to estimate demand for herbicide safety.

Section two explains why survey methods were used to generate the data needed to estimate demand. Section three describes how a mail questionnaire was designed and pretested. Section four describes sample selection and response rates and assesses sample representativeness. Section five presents the descriptive statistics. Major conclusions are summarized in section six. Tables are contained in section seven. The mail questionnaire is in Appendix A. A telephone questionnaire for measuring non-response bias is in Appendix B.

Why Survey Methods Were Used

One approach for investigating whether there is a demand for safety is hedonics. As demonstrated by Beach and Carlson (1993), it is possible to develop measures of the health, environmental, and weed control attributes of herbicides and to estimate their implicit market price via hedonic price analysis. Although Beach and Carlson found evidence to support the existence of a market for herbicide safety, there are two drawbacks to using hedonic methods to achieve the research objectives outlined above. First, a formally organized market for herbicide safety does not exist. Beach and Carlson had to develop proxies for health and environmental safety attributes. It is not known how or if these proxies relate to product information actually used by purchasers. Moreover, implicit prices estimated from a hedonic price equation reveal market equilibria, not market demand, for safety attributes. Estimates of demand require the further step of regressing implicit price on demand and supply variables. This type of analysis requires data that is extremely difficult to acquire.

A second approach is to simulate a market for herbicide safety. In this approach, a hypothetical market scenario is developed and subjects are asked to indicate the choices they would likely make if such a market existed. One advantage of this method is that it allows examination of the product attributes of interest. Another advantage is that supply does not need to be estimated simultaneously. A third advantage is that a private good is involved thus reducing the free-riding problems typically associated with constructed market methods (Carson, 1991). The obvious drawback is that the simulation is hypothetical. To insure that respondents perceive the hypothetical good properly and uniformly, researchers must describe both the good and its market in detail. The necessary detail is difficult to achieve in a succinct questionnaire, especially one aiming to cover multiple crops, pesticides, or safety attributes. This weakness undermines the credibility of other surveys of farmer demand for safer herbicides (Higley and Wintersteen, 1992; Mullen, Norton, and Reaves, 1997).

To reduce the problem of hypothetical bias, the simulation approach of van Ravenswaay and Hoehn (1991) was adopted. This approach involves simulating a market for a private good similar to one in which respondents are already very familiar but with small variations in the attributes of the good. Hypothetical bias is reduced because respondents are more likely to understand the market scenario and able to predict their likely choices. Respondents are asked a number of questions about their actual purchases of the familiar good at different prices and, from this data, demand for the familiar good is estimated. They are also asked how they currently evaluate a particular attribute of that good (e.g., safety). Finally, they are asked which "brand" they would choose given specified changes in the safety attribute and product price, assuming they had already planned to purchase some of the familiar good.

In this study, the familiar good was atrazine, a herbicide that is used by over ninety percent of corn producers. Corn producers were asked about their use of atrazine and to evaluate formulations of atrazine with fewer health and environmental effects. Prices and related market conditions were specified so that respondents would be encouraged to be evaluate similar market scenarios.

Either experimental or survey methods can be used to collect market simulation data. Experimental methods have the advantage of allowing greater control and realism of the market scenario given to respondents, but they do not permit statistical inference to an underlying population. Survey methods not only allow statistical inference but permit a wider range of variables to be examined. Therefore, a market was simulated using survey methods. The survey was conducted by mail rather than telephone since respondents were asked for information that may have required reference to farm records.

Questionnaire Design

The main purpose of the survey was to provide information that would allow demand, and thus willingness to pay, for safer herbicides to be estimated. The dependent variable is the herbicide formulation selected. The independent variables include standard micro-economic factors affecting derived demand for herbicides (e.g., own price, prices of substitutes, production factors such as weed pressure, and firm characteristics such as acreage), as well as factors likely to influence the demand for safety. Factors influencing the demand for safety reflect knowledge of the health and environmental effects of atrazine and the extent to which health and environmental effects are internal to the farm (e.g., use of a well for drinking water, proximity of the well to treated fields, proximity of fishing sites to treated fields, the presence of children in the farm household, and time spent on non-farming activities). In addition, pretesting revealed that another factor affecting the demand for safer herbicides was expectations about future regulatory behavior. Some farmers feel that regulation will become stricter if voluntary actions to reduce herbicide use are not taken.

To measure the dependent variable, corn producers were asked in July 1995 about their purchase and use of atrazine during the immediately previous (1995) spring planting season. Corn producers were then asked to consider what they might do the following year if weather, weed conditions, and weed control costs were the same but they had the option of purchasing either their current formulation of atrazine or another formulation, identical in every respect except for one safety attribute. Three different safety attributes were investigated in three different formulation scenarios. One formulation was described as not leaching into groundwater. A second formulation was described as not causing cancer in humans. The third formulation was described as not toxic to fish. Different respondents were offered different prices to consider. Three base prices of atrazine and five associated prices for the "new" formulations of atrazine made for 15 versions of the questionnaire (one of the versions is presented in Appendix 1). Respondents were asked whether they would choose regular atrazine or the safer formulation. Since pretesting of the questionnaire indicated that respondents were reluctant to assume new formulations would control weeds just as well as regular atrazine, we asked respondents how many acres they would use a new formulation on if, after three years of use, they had concluded it was as effective as regular atrazine. These purchase scenarios are in questions 17 through 24 of the questionnaire presented in Appendix A.

The three formulations examined were selected on the basis of a review of the published health and environmental effects of atrazine (Verschueren, 1983; Howard, 1991; Meister, 1994; University of California-Davis et al., 1995). Eleven health and environmental effects were identified and respondents were asked whether they had heard about each of the effects (question 14). They were also asked if they agreed with experts' assessment of the health and environmental effects of atrazine (question 15). The three health and environmental effects examined in the purchase scenarios were selected because they are the most widely known and most likely to be familiar to respondents. However, farmers were also asked about current sources of information about the health and environmental effects of herbicides (question 16).

Since demand for "new" herbicides depends on demand for regular atrazine, understanding farmers' use of and experiences with the chemical is important. Thus farmers were asked about use of chemicals containing atrazine and whether weeds resistant to atrazine were present in their corn fields (questions 10, 11, and 12). It was hypothesized that farmers with weeds resistant to atrazine would be less likely to purchase the "new" herbicides described as being nearly identical to regular atrazine. In addition, as many of the health and environmental effects of chemicals are not confined to the farm on which they are applied, respondents were asked about atrazine use in their area (question 13).

Farm firm characteristics hypothesized to influence the demand for regular atrazine and thus the safer formulations of atrazine, included total acreage farmed, acreage devoted to corn, weed pressure, and general farm management. Acreage has been included in virtually all studies dealing with use of environmental technologies, and the signs and significance level have varied depending on the specific technology examined (McNamara, Wetzstein, and Douce, 1991; Rahm and Huffman, 1994). Because of its importance in previous studies, farmers were asked about acreage (questions 3 and 4), but it is uncertain how demand will be influenced. Those farmers with severe weed problems (question 7) may need to rely on chemical methods of control more than farmers with slight weed pressure. Farm management practices such as no-till (question 8) and planting continuous corn (question 9) certainly influence weed management and likely influence the demand for herbicides.

Household characteristics hypothesized to influence the demand for safety included income, education, age, farming experience, number and age of children, hours worked off the farm, and sources of household income (questions 32 through 40). As with all normal goods, it was hypothesized that as income increases, the demand for safety also increases. Due to the sensitivity associated with supplying financial information, respondents were asked to indicate the interval in which their household income falls, rather than supplying their exact income (question 38).

Because education has been shown to enhance the likelihood of using environmental technologies (Taylor and Miller, 1978; Ervin and Ervin, 1982; McNamara, Wetzstein, and Douce, 1991), it was hypothesized that education would positively influence both the decision to purchase and demand the "new" formulations. Although age also has been shown to be influential in adoption studies, the sign of the impact has varied (D'Souza, Cyphers, and Phipps, 1993; McNamara, Wetzstein, and Douce, 1991). Experience may negatively influence willingness to pay as more experienced farmers may feel they know how to handle chemicals in such a way as to minimize risk.

Since children may be more susceptible to health problems from exposure to chemicals, it was hypothesized that farmers with young children would be willing to pay more for safer herbicides. Farmers who view farming as a way of life, rather than a business venture, have been found more likely to adopt environmental technologies (Pampel and van Es, 1977; Taylor and Miller, 1978; McNamara, Wetzstein, and Douce, 1991). Both hours worked off the farm and sources of income were designed as proxies for farm orientation. Farm characteristics influence the risk of health and environmental damage from atrazine. One avenue of potential exposure to agricultural chemicals is contaminated groundwater. Several factors including soil type, amount of irrigation, depth to groundwater, and proximity of corn fields to water sources influence the leaching potential of atrazine, as well as other chemicals (questions 5, 6, 28, and 31). Particularly important is whether farm households drink water that may be contaminated; thus, farmers were asked about their drinking water (questions 26, 27, 29, and 30). Knowledge of such factors may help determine how much risk of exposure respondents face. In addition, it was hypothesized that those whose chemical use is more likely to lead to contaminated groundwater would be willing to pay more for safer herbicides. Finally, one of the "new" herbicide formulations offered in the questionnaire was described as being non-toxic to fish. It was hypothesized that those near fishing sites would be willing to pay more for this formulation than those whose corn fields are not near fish. Therefore, respondents were asked about proximity of bodies of water containing fish to their corn fields (question 25).

To explore the possible effect on demand of future regulatory action, each of the purchase scenarios included a question asking respondents to identify the most important benefit they expected to get from purchasing a safer herbicide. The response categories included the possible benefit of less risk of future government regulation (questions 19 and 22).

A mail survey was chosen in order to provide farmers time to both think about their answers and check their records for certain information requested. For example, one of the questions asks about rate of use of certain herbicides as well as the number of acres on which these chemicals were applied. The survey design and mailing procedures followed the Dillman (1978) method. Drafts of the questionnaire were reviewed by members of the Michigan State University departments of Agricultural Economics and Crop and Soil Science, as well as by staff of the Michigan Agricultural Statistics Service.

Versions were pretested by Crop and Soil Science graduate students and technicians with farming backgrounds.

The Survey Sample

The sample for the study consisted of 2,000 Michigan corn farmers selected at random from the records of the Michigan Agricultural Statistics Service. A random sample was chosen to allow inferences about the entire population of Michigan corn farmers. The questionnaires were originally mailed in June 1995. Following the Dillman (1978) method, a reminder postcard was sent to the entire sample. Two follow-up questionnaire mailings were sent to nonrespondents three and seven weeks after the original mailing. A check of potential nonresponse bias was made by a short telephone survey (Appendix B) of a 15 percent random sample of non-respondents in October, 1995.

Response Rate

In total, 1,069 of the 2,000 questionnaires were completed and returned by respondents prior to the start of data analysis. Twenty-three additional questionnaires were returned as undeliverable. This resulted in an overall survey response rate of 54.1 percent.[4] Of the completed questionnaires returned, 324 were from non-farm households,

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[4]The response rate was calculated in the following manner:

$$\frac{\textit{completed questionnaires}\ (1069)}{\textit{number originally mailed}\ (2000) - \textit{number undeliverable}\ (23)}$$

71 were from farms that did not use herbicides, and 5 were unusable.[5] The total sample of responses analyzed consisted of 669 useable records from corn farms that use herbicides. Note that corn farmers who did not use herbicides were not asked questions about their farm or the purchase scenarios.

The follow-up survey of non-respondents involved telephone calls to 144 of the 931 non-respondents (i.e., 15.5%). Of these, 89 farmed corn and used corn herbicides. Six farmed corn, but did not use herbicide. The remainder did not farm corn.

Representativeness of Responses

To assess how well data from this study represents Michigan corn growers, comparisons were made between respondents and non-respondents. In addition, wherever possible, data gathered from this study were compared with those from a similar study. Landis and Swinton (1994) also surveyed Michigan corn farmers, but targeted a slightly different population. Rather than sample randomly, they sampled with the intent of representing Michigan corn acres rather than individual farms. No farms smaller than 25 acres were included in their study. Hence, their population characteristics differ slightly from those of this study. An additional source of comparison is the 1992 Michigan Census of Agriculture. Most of the information derived from this census pertains not to corn farms specifically but rather to all types of farms.

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[5]The Michigan Agricultural Statistics Service database is not continually updated. Therefore, from time the database was last updated to the time the survey originally commenced, many of those once growing corn were no longer farming for a variety of reasons including death, relocation, etc.

The average acreage farmed by respondents was 411 (Table 2.1). This is less than the average acreage farmed by non-respondents of 574. The Smith-Satterthwaite procedure was used to compare the mean acreage farmed by respondents with that of non-respondents.[6] Results indicate that, at 5 percent significance, the average acres farmed by the two groups is different, indeed non-respondents on average have larger farms. Respondents to the Landis and Swinton (1994) survey also indicated a larger farm size than respondents to this study, which is to be expected.

On average, approximately 162 of the 411 acres farmed by respondents were planted with corn. This is less than the 234 average acres planted with corn by non-respondents. Again, the Smith-Satterthwaite procedure was used to compare the mean acres of corn farmed by the two groups. Results indicate that at 5 percent significance, the null hypothesis of equal mean acres of corn farmed by the two groups cannot be rejected. In addition, the percentage of total acres planted with corn were similar for respondent and nonrespondent subsamples (39 percent and 41 percent, respectively).

Slightly more than half of respondents' household income was attributable to farming (Table 2.2). Results from the Smith-Satterthwaite procedure indicate that at 5 percent significance level, non-respondents, on average, received a greater portion of their income from farming than did respondents (66 percent versus 55 percent). These results are consistent with the Landis and Swinton study which found approximately 50 percent

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[6]The Smith-Satterthwaite procedure uses an approximate T statistic to compare means when variances are not equal. However, recent studies have shown that this procedure may also be used when variances are equal. For more information see Milton and Arnold, 1990.

to 70 percent of farm income was attributable to field corn. Non-respondents also attributed a greater portion of their household income to livestock than did respondents (32 percent and 22 percent, respectively).

The majority of respondents earned at least a high school diploma, with over 37 percent indicating at least some college attendance (Table 2.3). The educational levels among respondents was found to be different from that of non-respondents based on a Chi-Squared test of the proportions of each group indicating each educational level at the 5 percent significance level. Respondents were more educated than non-respondents. These results are also similar to those of Landis and Swinton (1994) with perhaps less representation of those with less than 12 years of education in the Landis and Swinton study.

The average age of farmers was slightly more than 50 (Table 2.4). This is consistent with the average age of all farmers according to the 1992 Agricultural Census. There is no reason to expect that corn farmers would be of different ages than other types of farmers. The farmers in this study were quite experienced, having farmed almost all years since their 18th birthday. In addition, the vast majority, slightly more than 95 percent of respondents, were male (Table 2.5). These results are also quite similar to those from the Census which found that 93.3 percent of farm operators were male. Again, there is no reason to expect that the gender profile of corn farmers would be different than that of other farmers.

Respondents to this study generally represent Michigan corn growers. However, several differences were found between respondents and non-respondents that may influence the interpretation of results from this study. Compared to non-respondents, respondents farm fewer total acres, attribute a smaller proportion of household income to farming, attribute a higher proportion of farm income to crops, and have higher education levels. Corn acreage was similar for the two groups. The net effect of these differences does not indicate a clear bias. Although respondents' smaller proportion of income from farming could reduce the risk of altering weed control practices, their greater reliance on crop income would have the opposite effect. The similar acreages in corn suggest little difference in added cost from any extra payments for safer herbicides on corn.

Descriptive Statistics

Since household and farm characteristics were presented above, this section begins by presenting the remaining household and farm characteristics data. Next the results on atrazine use and perceptions of the effects of atrazine on health and the environment are presented. Purchase intentions for the safer formulations of atrazine are presented last.

The majority of respondents indicated their annual household income was between $10,000 and $74,999 (Table 2.6). Approximately 34 percent indicated their household income was between $25,000 and $49,999. Only 4.6 percent indicated that their income was below $10,000 and only 10.2 percent indicated an income greater than $74, 999.

The average farm household size was 3.6 persons (Table 2.7). Less than 10 percent of the households had children under age 2 and/or between ages 3 and 5. More than 50 percent of the households had adults between ages 18 to 40 and/or between ages 41 and 64. On average, respondents worked off farm slightly more than 15 hours per week during May and June, some of the busiest months for farm work, including weed control (Table 2.8).

Most respondents indicated moderate weed pressure; only 12.9 percent described the weed pressure in their corn fields as severe (Table 2.9). Farm management practices such as no-till and planting corn continuously in the same field were followed by less than one-third of respondents (15 percent and 32 percent respectively) (Table 2.10). Slightly more than one-third of respondents' soil was sandy to sandy loam in texture. Less than 5 percent of respondents' corn fields were irrigated.

For over 83 percent of respondents, the primary source of drinking water was untreated and came from a private well (Table 2.11). Only 6.3 percent of well-owners treated their well water and less than 2 percent indicated bottled water as their primary source of drinking water. Bottled water may be consumed for a variety of reasons, one of which is to avoid consumption of contaminated water. Therefore, those who used bottled water were asked to indicate their primary reason for purchasing the product (Table 2.12). None indicated use of bottled water was due to well water contaminated by pesticides.

Over 90 percent of respondents indicated having a water well for household use, not necessarily just for drinking. Approximately 50 percent indicated their wells are between 100 and 500 feet away from their corn fields (Table 2.13). Only 16.9 percent had a well quite close to their corn fields. Respondents were also asked if they had ever tested their well water (Table 2.14). Of those who had a well for household use, only

34.8 percent had ever had it tested for the presence of agricultural chemicals. The majority found their wells to be clean and free of agricultural chemicals. Less than one percent had found evidence of atrazine in their well water. Finally, over half of respondents indicated that water containing fish was within 1/4 mile of their corn fields (Table 2.15).

Use of and Experience with Atrazine

Tables 2.16 through 2.20 present information on respondents' experience with atrazine. Over 86 percent of respondents indicated prior use of atrazine, reaffirming the view that atrazine is known widely to corn farmers (Table 2.16). Slightly more than half indicated the presence of weeds in their corn fields that are resistant to atrazine (Table 2.17). Over 50 percent believed that at least half of their farming neighbors use atrazine (Table 2.18).

A wide variety of herbicides containing atrazine are available to farmers, including Aatrex, Surpass 100, Extrazine, and Laddok. To learn about atrazine use, respondents were asked to indicate which, how much, and on how many acres atrazine-containing herbicides were applied. Approximately 72 percent of respondents used some form of atrazine in 1995. The herbicides most commonly applied by respondents were atrazine (Aatrex), Extrazine, Surpass 100, Bicep II and Bicep (Table 2.19). Less than 5 percent of respondents applied each of the other atrazine-containing herbicides. Of those indicating use of atrazine-containing herbicides almost 80 percent used only one such herbicide (Table 2.20). Only 17.1, 2.9, and 0.2 percent of respondents indicated they used two, three, or four atrazine-containing herbicides, respectively.

Awareness of Potential Need for "New" Formulations

More than 60 percent of respondents said they had heard that atrazine has a high probability of leaching (Table 2.21). Fewer than one-half of respondents were familiar with the fact that atrazine may cause cancer in humans, mild skin irritation, and severe eye irritation. Environmental effects such as slight toxicity to fish, mammals, and birds were known to between 30 and 45 percent of respondents.

When asked about their opinions concerning these published effects, many respondents doubted their validity (Table 2.22). Almost half were unsure whether atrazine is a possible human carcinogen. Surprisingly, 31.3 percent and 24.1 percent were unsure as to the validity of two of the most often published effects, lengthy soil half life and high leaching potential, respectively. Slightly more than one-quarter of respondents agreed that these two claims are valid. Less than 30 percent agreed that any single one of the other published effects is indeed true. In many cases, respondents felt that the effects given in the questionnaire were overstated. Slightly more than 23 percent felt that atrazine has less than a high probability of leaching, 17.5 percent felt that there was less than slight to moderate risk of toxicity to mammals, and 16.1 percent believed that there was less than a possible risk of cancer associated with atrazine use. Those respondents having previously heard of an effect of atrazine were more likely to state an opinion concerning the effect (Table 2.23). For example, almost 85 percent of respondents familiar with the fact that atrazine has a lengthy soil half life had an opinion concerning this environmental effect. Only 19 percent of those not previously familiar with this effect stated an opinion as to its validity.

On which sources do farmers depend for their information on health and environmental effects of herbicides (Table 2.24)? The two sources most often used on a regular basis were the label (71.7 percent) and the herbicide dealer (62.5 percent). One-third to one-half of respondents relied on their own experience, MSU Extension, and trade magazines for information. Other sources were used by less than one-quarter of respondents. This finding suggests that the most effective sources for presenting health and environmental information are the label and dealer. As less than half of respondents had heard of all but one of the environmental and health effects given in the questionnaire, perhaps these two sources are not effectively communicating existing information.

Purchase Intentions

Farmers were given the option of purchasing three "new" formulations of atrazine for possible use on their corn acreage. The price of atrazine was given as either $3.00, $3.75, or $4.50 per pound. The price of each of the new formulations was either the same as or $.50, $1.00, $3.00, or $5.00 more per pound than regular atrazine. Thus 15 price combinations were used. Farmers were then asked if and on how many acres they would apply each of the "new" formulations both next year and in three years time.

Respondents' willingness to purchase the "new" formulations for use next year tended to be inversely correlated with price (Tables 2.25-2.27). In most cases, fewer respondents indicated they would purchase any of the "new" formulations as the price of these formulations increased relative to the price of regular atrazine. For example, when the prices of both regular atrazine and the formulation described as non-toxic to fish were given as $3.00 per pound, 33 percent indicated they would purchase the formulation that is non-toxic to fish. Yet as the price of the formulation described as being non-toxic to fish increased by $.50, $1.00 and $3.00, only 29 percent, 23 percent, 16 percent, respectively indicated they would purchase this new formulation. When there was no price difference between regular atrazine and the "new" formulations, between 25 and 63 percent indicated willingness to purchase the "new" formulations. Disregarding relative prices, on average, 43 percent and 41 percent of respondents indicated they would purchase the formulations that do not cause cancer and do not leach, respectively. Less than one quarter indicated they would use the formulation that is non-toxic to fish.

Respondents were asked on how many acres they would apply the "new" formulations next year (Tables 2.28-2.30). Because pretesting of the questionnaire had indicated that farmers may be reluctant to change herbicides quickly and skeptical of claims made about new chemicals, respondents were further asked to state the acreage on which they would apply the "new" formulations in three years time. As with willingness to purchase, the average acres on which the chemicals would be applied decreased as the price difference between regular atrazine and the "new" formulations increased.

Moving from the one-year to the three-year time horizon, respondents would increase the acreage on which they applied the formulation non-toxic to fish (with one exception, the $3.00 price of regular atrazine with $6.00 price of "new" formulation). For the entire sample, those who would purchase the non-carcinogenic formulation would apply it on an average of 132 acres per farm next year and 157 acres per farm in three years. Since the average acres of corn planted per farm is approximately 162, this indicates great willingness to use herbicides that are safer to humans. Respondents indicating they would purchase the formulation described as not causing cancer stated they would use this on 81.5 percent of their corn acres next year and on 97 percent of their corn acres in three years.[7]

What benefits do corn growers expect to receive as a result of purchasing the "new" formulations? Respondents were asked to indicate the most important benefit from using the "new" formulations. The leading expected benefits for the formulation that does not leach are reduced health risk to household members (26.2 percent) followed by less risk of government regulation (24.4 percent) (Table 2.31). In contrast, for the atrazine formulation that does not cause cancer, reduced health risk was much more widely cited both for the household (42.6 percent) and for other people (16.2 percent) (Table 2.32). Reduced risk of government regulation was viewed as the greatest benefit by far fewer respondents for the non-carcinogenic formulation (12.3 percent) than for the non-leachable formulation (24.4 percent).

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[7]Found by dividing average number of acres on which "new" formulation would be applied by average acres of corn.

Conclusions

A variety of farm, household, and risk characteristics must be accounted for in estimating the demand for safer herbicides. Measures of these characteristics were described and results were presented for a representative sample of Michigan corn producers. We will use these results in our future research on estimating the demand for safer herbicides and the benefits of safety labeling.

Most of the respondents indicated that they are not familiar with many of the health and environmental effects of atrazine, one of the most commonly used corn herbicides. When presented with some of these health and environmental effects, respondents often doubted their validity. Respondents reported that they mainly relied on commercial sources for safety information, though product labels were also stated as important. An interesting future research question is whether doubts about the health and environmental effects of atrazine are related to the kinds of information sources farmers depend on most.

At least 30 percent of respondents are willing to pay up to $3.00 more per pound for formulations of atrazine that do not cause cancer in humans or that do not leach. Respondents indicating that they would purchase these chemicals would apply them on 64.2 percent (non-leaching formulation) to 81.8 percent (non-carcinogenic formulation) of corn acreage next year. Average acres on which these chemicals would be applied after three years increases to greater than 90 percent of the corn acreage operated by respondents willing to adopt the new formulations. Thus, if the new formulation is proven to work as claimed, more of it would be used per farm. Willingness to purchase one of the safer formulations of atrazine appears to be significantly related to the price difference over ordinary atrazine.

Tables[7]

Table 2.1 - Acres Farmed and Acres in Corn

	Respondents					Non-respondents					Landis & Swinton
	Mean	St. Dev.	Min.	Max.	Num	Mean	St. Dev.	Min.	Max.	Num	Mean
Aces farmed	411	573	2	6200	654	574	806	30	5300	83	865
Acres planted with corn	162	270	2	3500	661	234	449	9	3000	81	417

Table 2.2 - Income Sources

	Respondents					Non-respondents				
	Mean	St. Dev.	Min.	Max.	Num.	Mean	St. Dev.	Min.	Max.	Num
Percent of income from farming	55	36	0	100	591	66	33	2	100	66
Percent of income from livestock	22	32	0	100	593	32	33	0	100	78

[7]In all tables, percentages may not add to 100 due to rounding.

Table 2.3 - Education Level

Educational level	Respondents (N=669)	Non-respondents (N=89)	Landis & Swinton (N=723)
Less than 12 years	11.4%	12.4%	6.4%
Completed high school	39.5%	56.2%	38.5%
Technical training	8.1%	3.4%	11.9%
Some college	22.4%	14.6%	21.3%
Completed college	11.5%	6.7%	8.3%
Some graduate work	3.0%	0.0%	3.9%
Graduate degree	1.8%	3.4%	
No answer	2.4%	3.4%	9.8%

Table 2.4 - Age and Farming Experience

	Respondents					Census
	Mean	St. Dev.	Min.	Max.	Num.	Mean
Age	51	13	21	89	655	52
Years farming since age 18	29	14	0	74	654	----

Table 2.5 - Gender

Gender	This Study (N=669)	Census[8]
Male	95.2%	93.3%
Female	1.8%	6.7%
No answer	3.0%	-----

Table 2.6 - Farm Household Income Category Frequency (N=669)

Less than $9,999	4.6%
$10,000 - $24,999	24.5%
$25,000 - $49,999	34.2%
$50,000 - $74,999	14.2%
Greater than $75,000	10.2%
No answer	12.3%

Table 2.7 - Farm Household Size and Age Profile (N=669)

Average farm household size	3.59
Percent of farm households with children age 2 and under	6.4%
Percent of farm household with children ages 3 to 5	9.1%
Percent of farm households with children ages 5 to 7	32.4%
Percent of farm households with adults ages 18 to 40	52.0%
Percent of farm households with adults ages 41 to 64	54.1%
Percent of farm households with adults age 65 and over	17.3%

[8]All farmers. Found by dividing number of male farm operators by total and by dividing number of female operators by total.

Table 2.8 - Hours Worked off Farm During May and June

Mean	St. Dev.	Min.	Max.	Number
15.2	21.5	0	91	620

Table 2.9 - Perceived Weed Pressure in Corn Fields (N=669)

Slight	22.1%
Moderate	63.9%
Severe	12.9%
No answer	3.0%

Table 2.10 - Selected Farm Characteristics

	Mean	St. Dev.
Percent of acreage on which no-till is practiced (N=662)	15	32
Percent of corn acreage in corn for at least two years (N=661)	32	36
Percent of soil that is sandy to sandy loam (N=656)	39	34
Percent of fields irrigated (N=655)	3	14

Table 2.11- Primary Drinking Water Source (N=669)

Bottled water	1.9%
Untreated water from private well	83.3%
Treated water from private well	6.3%
Municipal water	3.3%
More than one source	1.4%
No answer	3.7%

Table 2.12 - Reason for Purchasing Bottled Water (N=21)

Well water tastes bad	69%
Other	15%
More than one answer	8%
No answer	8%

Table 2.13 - Distance from Well to Nearest Corn Field (N=621)

Less than 100 feet	16.9%
Between 100 and 500 feet	50.6%
Greater than 500 feet	30.3%
No answer	2.3%

Table 2.14 - Household Wells Tested for Contamination (N=669)

No	62.3%
Yes	34.8%
No answer	2.9%
If yes, results of test	
Well water clean, no chemicals found, etc.	60.5%
Nitrates found	2.8%
Atrazine found	0.5%
Other	6.5%
No answer/Don't know	29.8%

Table 2.15 - Water Containing Fish Near Corn Fields (N=669)

Yes	38.9%
No	55.8%
No answer	5.4%

Table 2.16 - Use of Atrazine Prior to 1995 (N=669)

Yes	86.8%
No	8.7%
No answer	4.5%

Table 2.17- Weeds Resistant to Atrazine in Corn Fields (N=669)

Yes	40.5%
No	52.9%
No answer	6.6%

Table 2.18- Proportion of Neighboring Farms Using Atrazine (N=669)

Less than 1/4	14.5%
1/4 to ½	15.7%
½ to 3/4	22.7%
3/4 to all	29.1%
No answer/Don't know	18.0%

Table 2.19- Frequency of Herbicides Used That Contain Atrazine

Herbicide	Number Using	Percent
Atrazine	270	40.4%
Extrazine	68	10.2%
Surpass 100	48	7.2%
Bicep II	42	6.3%
Bicep	40	6.0%
Marksman	33	4.9%
Harness Xtra	29	4.3%
Bullet	29	4.3%
Bicep Lite	14	2.1%
Guardsman	13	1.9%
Buctril-Atrazine	8	1.2%
Lariat	5	0.7%
Laddok	4	0.6%
Sutazine	3	0.4%
Shotgun	2	0.3%
None/No answer	183	27.4%

Table 2.20 - Use of Herbicides Containing Atrazine - Those Using at Least One

Percent of respondents using 1 herbicide containing atrazine	79.8%
Percent of respondents using 2 herbicides containing atrazine	17.1%
Percent of respondents using 3 herbicides containing atrazine	2.9%
Percent of respondents using 4 herbicides containing atrazine	0.2%

Table 2.21- Familiarity with Health and Environmental Effects of Atrazine

Effect	Have Heard About Effect	Have Not Heard About Effect
High probability of leaching	60.7%	39.3%
Possible human carcinogen	46.2%	53.8%
Slightly toxic to fish	45.3%	54.7%
Lengthy soil half-life	41.3%	58.7%
Mild skin irritant	41.0%	59.0%
Severe eye irritant	34.5%	65.5%
Slightly to moderately toxic to mammals	33.9%	66.1%
Slightly toxic to birds	30.3%	69.7%
May Irritate mucus membrane	21.5%	78.5%
Non-toxic to bees	10.8%	89.2%
Not a reproductive toxin	9.4%	90.6%

Table 2.22 - Opinions Concerning Health and Environmental Effects of Atrazine

Effects	Agree	Disagree the Effect is More	Disagree The Effect is Less	Unsure	No Answer
	Percent				
High probability of leaching	30.8	2.1	23.8	24.1	19.3
Possible human carcinogen	16.4	1.2	16.1	46.5	19.7
Slightly toxic to fish	25.6	3.6	13.5	36.2	21.2
Lengthy soil half-life	32.9	4.3	8.4	31.3	23.3
Mild skin irritant	27.7	1.6	17.5	31.2	22.0
Severe eye irritant	23.8	2.2	14.9	35.6	23.5
Slightly to moderately toxic to mammals	18.8	1.5	17.5	40.2	22.0
Slightly toxic to birds	16.7	2.8	16.1	40.7	23.6
May irritate mucus membrane	15.5	1.3	13.3	44.8	25.0
Non-toxic to bees	11.2	2.5	8.7	49.2	28.4
Not a reproductive toxin	6.9	1.5	9.9	54.6	27.2

Table 2.23 - Knowledge and Opinions of Effects of Atrazine (N=669)

Effects	Have Heard of Effect		Have Not Heard of Effect	
	Have an Opinion	Unsure/ No Answer	Have an Opinion	Unsure/ No Answer
	Percent			
High probability of leaching	75.1	24.9	28.1	71.9
Possible human carcinogen	51.1	48.9	18.9	81.1
Slightly toxic to fish	69.3	30.7	20.5	79.5
Lengthy soil half-life	84.4	15.6	19.1	80.9
Mild skin irritant	64.9	35.1	24.3	75.7
Severe eye irritant	72.3	27.7	24.5	75.5
Slightly to moderately toxic to mammals	58.1	41.9	27.4	72.6
Slightly toxic to birds	62.1	37.9	24.3	75.7
May irritate mucus membrane	65.3	34.7	20.3	79.7
Non-toxic to bees	50.0	50.0	34.0	66.0
Not a reproductive toxin	45.5	55.5	15.6	84.4

Table 2.24 - Sources of Information Used (N=669)

Source	Use Regularly
Chemical label	71.7%
Herbicide dealer	62.5%
Own experience	42.5%
MSU Extension	41.9%
Trade magazine	34.8%
Material safety data sheets	24.7%
Chemical company salesman	23.3%
Another farmer	22.3%
Custom applicator	16.9%
Consultant/Agronomist	13.5%
Newspapers	13.2%
Other	3.0%

Table 2.25 - Purchase of Non-Leaching Atrazine Formulation

Price of Atrazine	Price of New Formulation	Number Responding	Percent of Respondents		
			Purchasing New Formulation	Not Purchasing New Formulation	Not Answering/ Don't Know
$3.00	$3.00	43	63	33	5
$3.00	$3.50	48	48	46	6
$3.00	$4.00	47	38	49	13
$3.00	$6.00	51	35	59	6
$3.00	$8.00	42	21	67	12
$3.75	$3.75	48	44	52	4
$3.75	$4.25	42	45	41	14
$3.75	$4.75	51	49	45	6
$3.75	$6.75	44	34	61	5
$3.75	$8.75	37	27	68	5
$4.50	$4.50	36	53	44	3
$4.50	$5.00	40	53	43	5
$4.50	$5.50	47	53	40	6
$4.50	$7.50	47	32	66	2
$4.50	$9.50	46	13	76	11
Entire Sample		669	41	53	7

Table 2.26 - Purchase of Non-Carcinogenic Atrazine Formulation

Price of Atrazine	Price of New Formulation	Number Responding	Percent of Respondents		
			Purchasing New Formulation	Not Purchasing New Formulation	Not Answering/ Don't Know
$3.00	$3.00	43	54	35	12
$3.00	$3.50	48	50	46	4
$3.00	$4.00	47	45	40	15
$3.00	$6.00	47	30	59	10
$3.00	$8.00	42	14	76	10
$3.75	$3.75	44	40	52	8
$3.75	$4.25	42	48	38	14
$3.75	$4.75	51	53	43	4
$3.75	$6.75	44	41	52	7
$3.75	$8.75	37	32	60	8
$4.50	$4.50	36	47	44	8
$4.50	$5.00	40	60	35	5
$4.50	$5.50	47	49	43	9
$4.50	$7.50	47	47	51	2
$4.50	$9.50	46	26	65	9
Entire Sample		669	43	49	8

Table 2.27 - Purchase of Fish-Safe Atrazine Formulation

Price of Atrazine	Price of New Formulation	Number Responding	Percent of Respondents		
			Purchasing New Formulation	Not Purchasing New Formulation	Not Answering/ Don't Know
$3.00	$3.00	43	33	54	14
$3.00	$3.50	48	29	58	13
$3.00	$4.00	47	23	55	21
$3.00	$6.00	51	16	71	14
$3.00	$8.00	42	10	79	12
$3.75	$3.75	48	31	58	10
$3.75	$4.25	42	26	52	21
$3.75	$4.75	51	18	70	12
$3.75	$6.75	44	21	68	11
$3.75	$8.75	37	19	73	8
$4.50	$4.50	36	25	67	8
$4.50	$5.00	40	40	50	10
$4.50	$5.50	47	40	45	15
$4.50	$7.50	47	28	68	4
$4.50	$9.50	46	11	80	9
Entire Sample		669	25	63	12

Table 2.28 - Average Acres on Which Non-Leaching Formulation Would Be Applied

Price Of Atrazine	Price Of New Formulation	Average Acres	
		Next Year (N=249)	In Three Years (N=233)
$3.00	$3.00	114	154
$3.00	$3.50	121	139
$3.00	$4.00	106	114
$3.00	$6.00	82	111
$3.00	$8.00	76	106
$3.75	$3.75	129	156
$3.75	$4.25	136	257
$3.75	$4.75	143	317
$3.75	$6.75	60	72
$3.75	$8.75	51	56
$4.50	$4.50	113	131
$4.50	$5.00	66	81
$4.50	$5.50	109	145
$4.50	$7.50	88	117
$4.50	$9.50	48	70
	Entire Sample	104 (125[9])	149 (237)

[9]Standard deviations in parentheses.

Table 2.29 - Average Acres on Which Non-Carcinogenic Formula Would Be Applied

Price Of Atrazine	Price Of New Formulation	Average Acres	
		Next Year (N=245)	In Three Years (N=241)
$3.00	$3.00	123	145
$3.00	$3.50	128	164
$3.00	$4.00	118	127
$3.00	$6.00	101	112
$3.00	$8.00	60	75
$3.75	$3.75	140	168
$3.75	$4.25	161	191
$3.75	$4.75	298	371
$3.75	$6.75	51	61
$3.75	$8.75	49	58
$4.50	$4.50	166	172
$4.50	$5.00	70	84
$4.50	$5.50	165	168
$4.50	$7.50	78	110
$4.50	$9.50	105	169
	Entire Sample	132 (274)	157 (319)

Table 2.30 - Average Acres on Which Fish-Safe Formulation Would Be Applied

Price Of Atrazine	Price Of New Formulation	Average Acres	
		Next Year	In Three Years
$3.00	$3.00	124	149
$3.00	$3.50	89	106
$3.00	$4.00	102	120
$3.00	$6.00	65	61
$3.00	$8.00	89	108
$3.75	$3.75	148	168
$3.75	$4.25	131	192
$3.75	$4.75	213	386
$3.75	$6.75	70	78
$3.75	$8.75	64	72
$4.50	$4.50	82	87
$4.50	$5.00	76	88
$4.50	$5.50	149	157
$4.50	$7.50	88	109
$4.50	$9.50	69	95
	Entire Sample	110 (162)	138 (268)

Table 2.31- Perceived Benefit from Using Non-Leaching Formulation (N=271)

Less health risk to household	26.2%
Less health risk to other people	16.6%
Less risk of future gov. regulation	24.4%
Less risk to animals	1.5%
Other	2.9%
More than one answer	28.4%
No answer	2.6%

Table 2.32 - Perceived Benefit from Using Non-Carcinogenic Formulation (N=284)

Less health risk to household	42.6%
Less health risk to other people	16.2%
Less risk of future gov. regulation	12.3%
Other	1.2%
More than one answer	21.5%
No answer	6.3%

Chapter 3

DOUBLE-HURDLE ANALYSIS FOR ALTERNATIVE ATRAZINE FORMULATIONS[10]

Introduction

Farmer adoption of less environmentally harmful methods of pest control is an important goal of current U.S. agricultural policy. It is well documented that use of some chemical pesticides can adversely affect both human health and the environment. Farm worker exposure to herbicides has been associated with both chronic and acute health effects such as non-Hodgkin's lymphoma and leukemia (Blair and White, 1985; Hoar et al., 1986; Wigle et al., 1990). At times, herbicides in surface and groundwater drinking water supplies exceed threshold levels specified under the Safe Drinking Water Act (Ribaudo, 1993). Adverse effects on the environment also include fishery losses and a variety of effects on other species of wildlife such as birds and alligators (Hileman, 1994).

It is usually assumed that a safer, but equally effective, means of pest control will not be voluntarily adopted if it is more costly for farmers to use. However, this assumption may be false if some of the environmental problems caused by current pest

[10]An earlier version of chapter appeared as: Owens, N., S., Swinton, and E. van Ravenswaay. "Double Hurdle Marketing Analysis for Safer Herbicides. Selected Paper presented at the American Agricultural Economics Association Annual Meeting, July 27-30, 1997, Toronto, ON, Canada.

control methods are internal to farms. In such instances, the full private cost of farming is not fully reflected in farm accounts so that adopting a higher cost, but safer pest control method may minimize total private costs. It is also commonly assumed that pesticide users ignore the external impacts of farm chemicals when making pest control decisions. This assumption is reflected in current approaches to regulation of pesticides. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Food Quality Protection Act (FQPA) direct the U.S. Environmental Protection Agency to determine whether the use of a pesticide (including herbicides) results in excessive risks. In addition, some states have put additional restrictions on pesticide use. For example, Wisconsin has imposed regional bans on the use of certain herbicides, while Michigan and Iowa have levied input taxes on pesticides.

A small body of published information has challenged the assumption that safer but more costly pest control methods will not be adopted (Beach and Carlson, 1993; Higley and Wintersteen, 1992; Mullen, Norton, and.Reaves, 1997). These studies provide evidence that farmers are concerned about environmental and health effects of pesticides and are willing to pay to reduce these effects. In other words, farmers may be willing to use higher cost, but safer pest control methods simply out of concern for human health and the environment. If so, there may be opportunities to reduce pesticide risks through voluntary measures rather than the command approach used currently.

For obvious reasons, most studies of technology adoption on farms have been conducted after the technology has been introduced (Feder, Just, and Zilberman, 1985). This knowledge is certainly useful for monitoring and evaluation purposes. However, for technology research and development as well as for regulatory purposes, it is instructive to know *prior* to the introduction of the technology: 1) estimated willingness to adopt, 2) factors influencing the decision to adopt, and 3) factors influencing the intensity of use.

This paper presents results of a empirical study designed to provide an *ex ante* analysis of adoption and use of more environmentally friendly herbicides. As a benchmark for looking at safer herbicides, this study focuses on the case of atrazine used for weed control in corn. Atrazine is well-known to corn growers, as it is used on over 65 percent of U.S. corn acreage (Ribaudo and Bouzaher, 1994). In addition, a variety of adverse health and environmental effects have been associated with atrazine including contamination of groundwater and cancer in humans (Blair and White, 1985; Wigle et al., 1990; Ribaudo and Bouzaher, 1994). In a survey of Michigan corn farmers, Owens, Swinton, and van Ravenswaay (1997) offered respondents the option of purchasing either atrazine or a hypothetical "new" formulation of atrazine, one described as non-leaching, one described as non-carcinogenic, and one described as non-toxic to fish. Thus, three specific safer herbicides are examined. This paper estimates factors influencing the decision to adopt the non-leaching, non-carcinogenic, and fish-safe herbicides as well as the factors influencing the herbicides' intensity of use, conditional on adoption.

Statistical Method

A farmer's decision to use a safer pesticide may be viewed as a two stage decision. In the first stage, the farmer decides *whether* or not to use any of the safer alternative. In the second stage, he or she decides *how much* to use. The first stage is called the adoption decision and the second stage is the consumption decision. The Cragg double-hurdle model (1971) can be used to explicitly model this two-stage decision process. Unlike models such as the tobit that allow for a discrete mass point for observations as well as a continuous range of values for the dependent variable, the power of the double-hurdle lies in its ability to separate the decision to adopt from the decision of how much to consume given consumption. Both the variables influencing adoption and consumption as well as the magnitude and direction of the effect are allowed to differ. The double-hurdle model takes the form:[11]

$$\begin{aligned} y_i &= 0 \quad \text{if } w_i^* \leq 0 \\ y_i &= 1 \quad \text{if } w_i^* > 0 \end{aligned}$$

where,

$$w_i^* = B_2 z_{2i} + v_i.$$

The underlying variable w_i is unobserved; what is observed is y_i, whether or not the pesticide was used.

Conditional on $w_i^* > 0$,

$$\begin{aligned} \rho_i &= B_1 z_{1i} + u_i \quad && \text{if } B_1 z_{1i} + u_i > 0 \\ \rho_i &= 0 && \text{if } B_1 z_{1i} + u_i \leq 0. \end{aligned}$$

[11]The presentation of the Cragg model borrows heavily from Bockstael et al. (1990).

Here, ρ is the quantity of the pesticide used and z_{1i} and z_{2i} are vectors of individual characteristics of the *i*th individual, v_i is $N(0, \sigma^2_v=1)$, and u_i is $N(0, \sigma^2_u)$. The individual farmer may indicate he would not purchase the pesticide for one of two reasons; he may choose not to purchase because of factors in either the z_1 or z_2 vector.

The likelihood function is given by

$$\prod_{i\in n}\Phi(-B_2 z_{i2}) \prod_{i\in a}\Phi(B_2 z_{i2}/\sigma_u)\sigma_u\phi(y_i/\sigma_u - B_1 z_{i1}/\sigma_u)/\Phi(B_1 Z_{i1}).$$

Here *n* is the subset of non-adopters and *a* is the subset of adopters. 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 regression. The second stage, the consumption decision, is estimated using a truncated regression.

Data Source

The data used in this study comes from a survey conducted by Owens, Swinton, and van Ravenswaay (1997). Respondents to the survey were asked in 1995 to consider whether they would use, in 1996, regular atrazine or a hypothetical alternative atrazine formulation. 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 at specified prices and market conditions. 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 survey sample was partitioned so that each respondent faced a choice on only one price pair. Respondents were asked whether they would use the "new" formulation at the stated prices (the adoption decision) and, if so, on how many acres this formulation would be applied (the consumption decision). Respondents were asked about consumption both in the year immediately following the survey (referred to as "next year" for the remainder of the paper) and in three years (referred to as "three years"), if the "new" formulation had performed as indicated.

Respondents also answered questions about 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 survey had an overall response rate of 54 percent, including 656 respondents (35 percent) who both used herbicides and grew corn.

Dependent and Independent Variables

The adoption decision was modeled as a probit regression where the dependent variable indicated willingness to use the "new" atrazine formulation (ADOPTL is used for the non-leaching formulation, ADOPTC is used for the no-cancer formulation, and ADOPTF is used for the fish-safe formulation). The consumption decision was modeled as a truncated regression where the dependent variable was the number of corn acres on which the respondent would use the "new" formulation in question. The dependent variables were ACRES APPLIEDL (non-leaching formulation), ACRES APPLIEDC (no-cancer formulation) or ACRES APPLIEDF when acres applied was non-zero. Consumption in three years was measured in the same manner and also modeled as a truncated regression. Definitions of relevant variables are presented in Table 3.1.

The Owens, Swinton, and van Ravenswaay (1997) survey gathered data on a variety of factors expected to influence both adoption and consumption of the three hypothetical atrazine formulations. The focal issue is the farmer's trade-off. In the case of the non-leaching atrazine formulation, the trade-off is between increased weed control cost and averting groundwater leaching from atrazine (which may mean averting other adverse health and environmental effects). With the non-carcinogenic formulation, the trade-off is between increased herbicide cost and averting a possible adverse human health effect. Similarly, with the fish-safe formulation, the trade-off is between increased cost and protecting fish. Thus, price differences between the "new" formulations and regular atrazine and risk perceptions were expected to be influential variables.

The difference in price between atrazine and the new alternative was expected to be a key variable in both the adoption and consumption decisions. It was hypothesized that as the new formulation became more expensive relative to regular atrazine, the probability of adoption of all three alternative formulations would decrease. Likewise, it was hypothesized that as the new formulation became more expensive relative to regular atrazine, consumption of the three alternative formulations would decline.

For environmental costs of atrazine use to be internal to a farm, the farmer must perceive exposure to atrazine. Thus, adoption of the safer, non-leaching alternative to atrazine should increase with an increase in farmers' perceptions of atrazine's potential to leach into and remain in groundwater used by the farm. Adoption of the non-carcinogenic formulation should increase with awareness of the potential carcinogenicity of atrazine. Similarly, adoption of the fish-safe formulation should increase with awareness of atrazine's potential to harm fish. This awareness was measured in a two ways. First, respondents were asked if they knew that atrazine has a high leaching potential in most soil types, has been classified as a possible human carcinogen, and is slightly toxic to fish. Second, farmers were asked if they agreed with current scientific opinion concerning the leaching potential, carcinogenicity, and fish toxicity of atrazine or believed scientists understated or overstated these effects.

A variety of characteristics were also hypothesized to be important in determining risk. One potential avenue of human exposure to agricultural chemicals is through drinking water. It was hypothesized that those whose primary source of drinking water was untreated well water would be more likely to adopt the non-leaching and perhaps non-carcinogenic atrazine formulations. In addition, it was felt that knowledge of water contamination would also affect adoption and perhaps consumption of these formulations. However, the direction of the effect was uncertain *a priori*. Those with uncontaminated water may be less likely to adopt due to a belief that because their current chemical use has not led to contamination, a safer chemical is not needed. Similarly, those with contaminated water may be less likely to adopt due to the belief that because the water is already bad, switching is pointless. Finally, a question dealing with the proximity of fish to the farm was also included. It was hypothesized that those in close proximity to fish would have both a higher probability of adopting and greater intensity of use of the fish-safe formulation. Although risk perceptions were expected to be important, because of the controversy surrounding atrazine and the re-registration process that agricultural chemicals are required to undergo, it was thought that concern about future chemical regulation, rather than for health and environmental quality, may influence use of the "new" formulations. A variable designed to capture concern for future regulation was hypothesized to be influential.

In many previous studies dealing specifically with adoption of environmental innovations, farm orientation was found to be important. In an early study dealing specifically with adoption of practices designed to protect the environment, Pampel and van Es (1977) hypothesized that farm orientation is an important factor in explaining the adoption of environmental innovations. Specifically, those farmers who view farming as a way of life will be more likely to adopt environmental innovations, perhaps out of a sense of social responsibility. Farmers with the view that farming is more of a business venture will be more likely to adopt efficiency improving technologies. Thus, "way of life" farmers will tend to have a lower socioeconomic status than other farmers. Finally, those making their living totally from farming will be more likely to adopt environmental innovations. Farming orientation variables have been found to influence adoption of many environmental technologies (Pampel and van Es, 1977; Taylor and Miller, 1978; McNamara, Wetzstein, and Douce, 1991; D'Souza, Cyphers, and Phipps, 1993). One proxy for farm orientation is hours worked off farm. It was expected that hours worked off farm would negatively influence adoption of all three formulations. However, once the decision to purchase the safer herbicide has been made, it was uncertain if and how this variable would influence consumption of the three formulations.

Farm characteristics have generally been included in studies addressing agricultural technology adoption. However, the signs and significance level of farm characteristic variables have varied depending on the specific technology examined. As an illustration, McNamara, Wetzstein, and Douce (1991) found acreage to be insignificant in explaining peanut producers' decision to use integrated pest management while Rahm and Huffman (1984) found acreage positively impacted the probability that Iowa farmers adopt reduced tillage.

A variety of farm characteristics were expected to be influential in both the adoption and consumption decisions. These included corn acreage, household income, percent of income from livestock operations, and prior use of atrazine. No prior expectations were held regarding the direction of the effect of corn acreage in the adoption decisions. However, it was expected that consumption increase with acreage. As with all normal goods, it was expected that household income would positively influence adoption and consumption of all three alternative formulations. As the "new" chemicals were described as identical to regular atrazine, it was expected that familiarity with atrazine would favor adoption of all formulations, due to the belief that a farmer who is already familiar with some portion of the technology will be more likely to adopt.

Environmental characteristics of the farm included were the percentages of corn fields that were irrigated and those that were no-till planted. Also included were dummy variables indicating the presence of moderate to heavy weed pressure, the belief that more than half of neighboring farms use atrazine, and the presence of weeds resistant to atrazine. As the amount of irrigation carried out on farm increases, the risk of herbicide leaching increases. Thus, it was expected that irrigation would positively effect the probability of adoption of the non-leaching formulation and perhaps the non-carcinogenic formulation. Weed pressure was felt to be relevant, but no prior expectation of its sign were held, as herbicide efficacy was assumed the same for all formulations in the survey.

The effect of nearby use of atrazine on the probability of adoption and intensity was uncertain *a priori*. A farmer may be more likely to adopt or use more of the new formulations if he seeks to compensate for atrazine use on neighboring farms or he may be less likely to adopt or use if he feels helpless. Similarly, if a farmer's well has been shown to be contaminated, arguments in favor of both negative and positive impacts can be made.

Personal characteristics expected to be relevant were years of farming experience, education, and the presence and perhaps ages of children. Those with large livestock operations may be less concerned about and have less time to devote to crop farming, so a negative coefficient was expected in the adoption equations. Children may be more susceptible to adverse health effects associated with herbicide use. Therefore, it was expected that both adoption and perhaps consumption of the non-leaching and non-carcinogenic formulations would be positively influenced by the presence of children. Different sources present information on the health and environmental effects of chemicals differently. Therefore, it was expected that reliance on certain information sources would influence the adoption and consumption decisions for the new formulations, but no prior assumptions were made regarding the direction of influence. Because no prior published agricultural technology adoption research has separated adoption from consumption, no prior separation of variables was imposed. Both adoption and consumption of the formulations were hypothesized to be functions of all available variables.

Results

Descriptive statistics and regression results were estimated using LIMDEP Version 7.0 (Greene, 1995). Descriptive statistics are presented in Table 3.2. The mean level of adoption of the non-leaching formulation was 49 percent, with this formulation being used on an average of 99 corn acres per farm for those indicating use. The mean level of adoption of the non-carcinogenic formulation was 46 percent, being used on an average of 194 corn acres. The mean level of adoption for the fish-safe formulation was 29 percent, being used on an average of 123 corn acres. For the non-leaching formulation, the final samples consisted of 301 completed records for the adoption regression. One hundred forty seven and 146 completed records were used in the consumption regressions for next year and three years, respectively. For the non-carcinogenic formation, the final samples consisted of 352 completed records for the adoption regression. Consumption of this formulation was modeled using 163 completed records for both next year and three years. The final sample used to estimate adoption of the fish safe formulation consisted of 313 complete records. The final samples for consumption next year and in three years consisted of 90 and 88 complete records, respectively.

Non-Leaching Atrazine Formulation

Regression results for the non-leaching atrazine formulation are presented in Table 3.3. The variables retained in each model are those which could not be dropped based on Wald tests at the ten percent significance level.[12] All three equations in the model fit the data reasonably well. A measure of goodness of fit in binary dependent variable models is the likelihood ratio index (LRI) (Pindyck and Rubinfeld, 1991; Greene, 1993). The LRI for the adoption equation is 0.18, which falls into the range of 0.15 to 0.40 in recent studies examining the adoption of integrated pest management practices (Harper et al., 1990; Swinton, Cuyno and Lupi, 1995). The decision to adopt was predicted correctly 69.4 percent of the time, while the decision not to adopt was predicted correctly 66.9 percent of the time. With the consumption equations, the likelihood ratio test provides evidence that the variables included were jointly significant at the 1 percent level.

The explanatory variables passing the Wald test differed markedly between the adoption and consumption equations, supporting the selection of a double hurdle approach rather than a tobit. In addition, the estimated coefficients of those variables included in both equations differed in magnitude, sign, and significance level. A prime example is ACRESCORN, whose estimated coefficient is negative and significant in the adoption equation and positive and significant in the consumption equations.

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[12]For consistency, all variables included in the "this year" regression were also included in the "three year" regression. Where additional variables found to be influential in "three years", they were included only in the "three year" regression.

Results from the probit regression indicate that the probability of purchasing the non-leaching formulation is enhanced by the belief that most neighbors use atrazine (USENEAR), the presence of weeds resistant to atrazine (RESIST), agreement with scientific evidence regarding the leaching risk of atrazine (LEACH), prior use of atrazine (ATRAZINE95), and income (INCOME). Factors that reduce the probability of purchasing the non-leaching formulation included corn acreage (ACRESCORN), the difference in price between regular atrazine and the non-leaching formulation (PRICEDIFFERENCE), farming experience (EXPERIENCE) as well as reliance on chemical dealers for information about the health and environmental effect of herbicides (DEALER). Where prior expectations were held regarding the sign of variables, signs are consistent with prior expectations, with the exception of that on RESIST.

The positive USENEAR coefficient suggests that farmers may try to compensate for the chemical use decisions of their neighbors. As microeconomic principles would predict, the difference in price between the new and conventional formulations of atrazine reduces the probability of adopting the new formulation. While there was no prior expectation concerning farm size, the negative coefficient on ACRESCORN suggests that farmers with larger corn acreage are less likely to adopt. Farm size may also be an indication of farm orientation, with those on larger farms being business oriented farmers and thus less likely to adopt this and other environmental technologies. The unexpectedly positive sign on RESIST shows that those farmers with weeds resistant to regular atrazine are more likely to purchase the new formulation, presumably in hopes that weeds will be susceptible to it. In addition, these results provide evidence that awareness of need for the alternative formulation, as measured by respondents' opinions on the leaching effect of atrazine related to those of the scientific community, also affects the probability of adoption of the non-leaching formulation. Those who agreed that atrazine has a high probability of leaching or felt this statement understated atrazine's leaching potential were more likely to choose to use this formulation.

Contrary to expectations, hours worked off farm, the proxy for farm orientation, did not have a significant effect on the probability of adoption. This result may be explained by the possible human health effects associated with herbicide use. That is, adoption of an herbicide that does not leach will not only protect farming resources (groundwater, etc), but may also positively impact human health (less possible exposure via groundwater). If all farmers, regardless of farm orientation, are equally concerned about both their own health as well as the health of their families, the adoption decision should not be affected by farm orientation.

Consumption of the non-leaching atrazine formulation was measured by the number of acres on which respondents indicated they would apply the new formulation. For those farms adopting this formulation, the truncated regression showed acres of use next year were enhanced by ACRESCORN, the percent of acres no-till farmed (NOTILL), INCOME, USENEAR and reliance on chemical dealers for pest control information (DEALER). Reliance on other farmers for pest control information (FARMER) and post-high school education (COLLEGE) detracted from the number of acres on which the new formulation would be applied.

The positive coefficient on ACRESCORN indicates that, although those with larger farms are less likely to adopt, those adopters with more corn acreage will buy more of the "new" atrazine formulation. The positive USENEAR coefficient provides further evidence that farmers try to compensate for the chemical use decisions of their neighbors. The positive coefficient on DEALER indicates that farmer adopters who rely on dealers for pest control information will use more of the non-leaching formulation. Those who rely on other farmers for pest control information (FARMER), however, will use less of the alternative formulation. While not significant at the 10 percent level, the sign of the estimated coefficients on the price variable is negative, as expected. The insignificance of the price variable (at 10 percent) in the consumption equation indicates that once the decision to purchase a safer chemical alternative has been made, price is less of a consideration. Most of the alternatives to atrazine are more expensive. Knowing this, it is reasonable for farmers to consider price only when deciding whether or not to move from using atrazine to another chemical.

Truncated regression results for consumption of this formulation in three years are similar to those for next year. The exception is that consumption in three years is affected by different sources of information. While reliance on dealers positively influences consumption in both years, use of chemical consultants and labels affects consumption in three years. Finally, the estimated coefficient on price difference is again insignificant.

Non-Carcinogenic Atrazine Formulation

Regression results for both the adoption and consumption equations for the non-carcinogenic formulation are presented in Table 3.4. The LRI for the adoption equation is 0.14, again falling into the range found in recent adoption studies (Harper et al., 1990; Swinton, Cuyno, and Lupi, 1995). The decision to adopt is predicted correctly 71.4 percent of the time, while the decision not to adopt the non-carcinogenic formulation is predicted correctly 69.3 percent of the time. The likelihood ratio test indicates the variables included in the consumption equations are jointly significant at the 1 percent level.

As with the non-leaching formulation, the explanatory variables passing the Wald test differed between the adoption and consumption equations. Results from the probit regression of the non-carcinogenic formulation indicate that the probability of adoption of this formulation is enhanced by USENEAR and ATRAZINE95, as well as by reliance on newspapers (PAPER) and Michigan State University extension personnel (MSU) for information. The probability of adoption of the non-carcinogenic formulation is reduced by ACRESCORN, IRRIGATION, EXPERIENCE, PRICEDIFFERENCE and MAGAZINE. Where prior expectations were held concerning the direction of effect, the signs of all variables were consistent with expectations, with the exception of that on IRRIGATE.

Again, the estimated coefficient on USENEAR is positive, providing further evidence that farmers may try to compensate for the chemical use decisions of their neighbors. The difference in price between the non-carcinogenic and conventional formulations of atrazine was again found to reduce the probability of adoption. The farm orientation proxy, HOURS WORK, does not appear in the regression for the no-cancer formulation, reinforcing the inference that "way of life" farmers and business oriented farmers are equally concerned about human health. Among information sources, reliance on MAGAZINE (many of which are financed by pesticide companies) tended to discourage adoption. In contrast, reliance on more independent information sources such as newspapers and extension favored the adoption of the non-carcinogenic formulation. As with the non-leaching formulation, the coefficient of PRICEDIFFERENCE is negative and highly significant.

For those farmers adopting the non-carcinogenic formulation, consumption next year is enhanced by ACRES CORN, NOTILL, DEALER and USENEAR, while post-high school education (COLLEGE) and PRICEDIFFERENCE again detracted from use. All signs were consistent with expectation with the exception of that of RESIST and CARCIN. These results are similar to those of the non-leaching formulation.

The negative coefficient on education in the consumption decisions of both formulations (as well as the negative coefficient on experience in the adoption decisions) may indicate those with higher education levels (experience) may feel they are more able to target use of hazardous chemicals and therefore only need to use these in most vulnerable areas (if at all). The coefficient on price difference is again insignificant (at 10 percent) providing further evidence that although price is a major factor in the decision to switch away from regular atrazine, once the decision has been made, price difference is not a consideration (at least up to the levels presented in the survey).

Concerns about human health, rather than of future government regulation, motivated farmers' choice of the non-carcinogenic formulation. Contrary to expectations, the estimated coefficient on CARCIN, a dummy variable indicating previous knowledge of the fact that atrazine has been classified as a human carcinogen, is negative. In addition, awareness of the need for alternative formulations as measured by opinions as to the carcinogenicity of atrazine are not important in either the adoption or consumption decisions. One possible explanation for this outcome includes the fact that the question did not account for respondents believing they had less risk of cancer due to personal actions (i.e., someone else sprays field). Another possible explanation deals with the cost of believing that atrazine does not cause cancer when it really does (that is, the cost of being mistaken). Although a farmer may believe that atrazine does not cause cancer in humans, if he/she is mistaken, the outcome (cancer) is possibly fatal to both family members and the individual. Thus, because the cost of a mistake is great, those believing atrazine causes cancer and those who do not may be equally likely to use the non-carcinogenic formulation.

The variables retained in the regression for consumption in three years are generally similar in sign and significance to those retained in the regression for consumption next year. Price difference again becomes even more insignificant. However, a few of the variables important in determining consumption next year, were not important in determining consumption in three years. As an example, consider health. In the regression for next year the estimated coefficient of this variable is positive and highly significant, yet in the regression for three years the estimated coefficient is insignificant. The author has no explanation for this result.

Fish-Safe Atrazine Formulation

Regression results for adoption and consumption of the fish-safe alternative are presented in Table 2.4. The LRI for the adoption equation is 0.12 which is below the range found in recent adoption studies (Harper et al., 1990; Swinton, Cuyno, and Lupi, 1995). The model poorly predicts the decision to adopt the fish safe-formulation, only 27.7 percent of adopters were correctly predicted to adopt this formulation. However, the decision not to adopt is predicted correctly 92.4 percent of the time. The likelihood ratio test indicates that the variables included in the consumption equations are jointly significant at 1 percent. As with the non-leaching and non-carcinogenic formulations, the explanatory variables included in the two stages differ in magnitude, sign, and significance.

Results from the probit regression indicate that the probability of purchasing the fish-safe formulation is enhanced by hours worked off farm, RESIST, USENEAR, and PAPER. Also enhancing the probability of adoption (while not significant at 10 percent) are risk the perception variables, having previously known atrazine is slightly toxic to fish (FISHTOX) and believing it is more than slightly toxic to fish (FISHM), as well as proximity to fish. The probability of adoption is diminished by EXPERIENCE and PRICEDIFFERENCE.

Many of these results are similar to those obtained for the other formulations, for example, USENEAR again positively and significantly influences adoption, while experience has a negative impact. However, there are some differences. First, corn acreage is not important in determining adoption of the fish-safe formulation. Second, hours worked off farm is influential, however, the sign of this variable is the opposite of what was expected. This result may indicate that those with less time to devote to farm operations are more apt to use a safer chemical rather than apply different chemicals to different areas of the farm.

Consumption next year was positively influenced by ACRESCORN, IRRIGATE, the presence of children, and reliance of chemical labels and salesmen. Consumption was negatively influenced by LIVESTOCK, COLLEGE, and PRICEDIFFERENCE. Two sources of information negatively influenced consumption; other farmers and consultants. While not significant at 10 percent, the coefficient on FISHM was the opposite of what was expected. Income is not an important determinant of use. Results for consumption in three years are similar. The signs and significance level of sources of information proving to be important were also similar, with the exception of PAPER.

Conclusions

These results indicate there is potential for voluntary adoption of more environmentally friendly pest control methods. Averaging over all price differences, approximately 50 percent of farmers indicated that they would use some of the non-leaching and non-carcinogenic formulations of atrazine. Fewer farmers, approximately 30 percent, indicated they would use the fish-safe alternative. Since the individuals indicating use of these formulations are presumably early adopters, it can be anticipated that adoption would rise over time. The survey results show that these early adopters would increase their use over time, if the formulation met expectations. Use of the non-leaching formulation would increase from an average of 99 to 130 acres, a similar pattern emerges for the non-carcinogenic and fish-safe formulations. Likewise, one would expect that if the chemicals performed as indicated others would adopt over time.

It should be kept in mind that the scenario presented to respondents represents the case of perfect information. In other words, the results suggest what the potential adoption would be if all producers knew of the new formulation and knew about the health and environmental effects of the conventional formulation. In the real world, a substantial marketing effort would be required to get 100 percent product recognition. Indeed, survey results found that only 60.7 percent of respondents were familiar with the fact that atrazine has a high probability of leaching in most soil types; less than half of respondents knew that atrazine has been classified as a possible human carcinogen (Owens, Swinton, and van Ravenswaay, 1997). Nonetheless, there is evidence that such a marketing effort could be worthwhile.

Perceptions of scientific knowledge about leaching potential appear to be important in the adoption decision of this formulation. There is some evidence that risk perceptions are important in adoption of the fish-safe formulation. Scientific evidence suggests that atrazine has a high probability of leaching. Respondents who agreed with or felt the scientific evidence understates the problem were more likely to decide to purchase the non-leaching formulation. Similarly, respondents believing atrazine is more than slightly toxic to fish were more likely to use the fish-safe formulation. This, coupled with low farmer awareness of the health and environmental risks associated with atrazine use, suggests that educational policies--perhaps including more comprehensible herbicide safety labeling--may be effective at encouraging voluntary use of more environmentally friendly technologies.

A variety of sources of information proved to be influential in determining adoption and consumption of the alternative atrazine formulations. While more research is needed to more completely describe the relationship between adoption/intensity of use and information, the results obtained here do suggest a pattern. Reliance on more independent sources of information, including newspapers, extension, and chemical labels, seems to encourage the adoption and use of more environmentally friendly chemicals. This result may indicate that these sources present crucial information on the health and environmental effects of chemicals more clearly than do other sources. While reliance on chemical dealers for information tended to discourage adoption of the non-leaching formulation, once the decision to adopt has been made, use of dealers for advice increased the intensity of use of both the non-leaching and non-carcinogenic formulations.

Researchers continue to try and develop new agricultural chemicals that pose less risk to human health and the environment. While it is not likely that the exact chemicals described in this paper will be developed, the results obtained here may be helpful in increasing adoption and use more environmentally friendly chemicals. Those with larger farms were less likely to adopt the non-leaching and non-carcinogenic formulations. However, corn acreage positively influenced use. Post-high school education and farming experience was an important detractor from demand of both the non-leaching and no-cancer atrazine formulations. The key issue seems to be one of skepticism about whether the new chemical will perform as claimed and perhaps the ability to safely use and/or target chemicals in vulnerable areas. This suggests that adoption of safer pesticides can be enhanced by insuring that new pesticides are efficacious and that credible pest control efficacy information is widely available.

Tables

Table 3.1 - Variables Included in Model

Variable	Units	Meaning
DEPENDENT		
ADOPTL	(0,1)	Use of non-leaching formulation
ACRES APPLIEDL	Acres	Area on which non-leaching formulation would be used
ADOPTC	(0,1)	Use of no-cancer formulation
ACRES APPLIEDC	Acres	Area on which no-cancer formulation would be used
ADOPTF	(0,1)	Use of fish safe formulation
ACRES APPLIEDF	Acres	Area on which fish-safe formulation would be used
INDEPENDENT		
FARM ORIENTATION		
HOURSWORK	Hours	Time worked off farm
FARM CHARACTERISTICS		
INCOME	1,000s of dollars	Household adjusted gross income
LIVESTOCK	%	Proportion of income from livestock
ACRESCORN	Acres	Area of corn farmed
ATRAZINE95	(0,1)	Used some form of atrazine in 1995
RESIST	(0,1)	Had weeds resistant to atrazine
IRRIGATE	%	Proportion of corn fields that are irrigated
NOTILL	%	Proportion of corn acres on which no till practiced
WEEDPRESSURE	(0,1)	More than slight weed pressure
UNTREATEDWATER	(0,1)	Primary source of drinking water is untreated well water
USENEAR	(0,1)	More than ½ of neighboring farms use atrazine
PERSONAL CHARACTERISTICS		
CHILDREN	(0,1)	Have children under age 18
EXPERIENCE	Years	Years of farming experience
COLLEGE	(0,1)	Education past high school
CONSULTANT	(0,1)	Relies on consultant for information
DEALER	(0,1)	Relies on dealer for information
FARMER	(0,1)	Relies on other farmers for information
LABEL	(0,1)	Relies on chemical label for information
MAGAZINE	(0,1)	Relies on trade magazine for information

Table 3.1 - (cont'd)

MSDS	(0,1)	Relies on material safety data sheets for information
MSU	(0,1)	Relies on MSU extension for information
PAPER	(0,1)	Relies on newspaper for information
RISK PERCEPTIONS		
CARCIN	(0,1)	Knew atrazine classified as possible human carcinogen
GOVREG	(0,1)	Most important reason to use no cancer formulation is risk of future regulation
FISH	(0,1)	Fish within 1/4 miles of corn fields
FISHM	(0,1)	Feels scientific opinion concerning fish toxicity
FISHTOX	(0,1)	Familiar with fact that atrazine slightly toxic to fish
LEACH	(0,1)	Agrees with or feel scientific opinion about leaching understated
CONTAMINATED	(0,1)	Well water contaminated from agricultural chemicals
PRICE		
	Dollars	Price difference between new and conventional atrazine

Table 3.2 - Descriptive Statistics

	Non-Leaching Formulation				No-Cancer Formulation			
	Entire Sample (N=301)		Purchasers (N=147)		Entire Sample (N=352)		Purchasers (N=163)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
ADOPTL	0.49	0.50	1.00	0.00				
ACRESAPPLIEDL	48.00	91.00	99.00	110.00				
ACRESAPPLIED TY			130.00	128.00				
ADOPTC					0.46	0.50	1.00	0.00
ACRES APPLIEDC					62.00	194.00	135.00	267.00
ACRESAPPLIED TY							154.00	305.00
HOURSWORK								
INCOME	43.30	26.80	43.80	27.40	41.20	26.00	41.50	26.30
LIVESTOCK	21.70	30.70	19.60	30.50	21.20	31.10	19.50	30.70
ACRESCORN	174.00	227.00	152.00	154.00	183.00	286.00	173.00	324.00
ATRAZINE95	0.80	0.40	0.89	0.31	0.79	0.41	0.87	0.34
RESIST	0.50	0.50	0.60	0.49	0.49	0.50	0.52	0.50
IRRIGATE					3.20	14.60	2.00	9.76
NOTILL	18.60	36.10	20.00	36.70				
WEED PRESSURE	0.77	0.42	0.78	0.42				
USE NEAR	0.68	0.47	0.80	0.40	0.66	0.47	0.79	0.41
UNTREATEDWATER					0.92	0.28	0.90	0.30
CHILDREN	0.48	0.50	0.48	0.50				
EXPERIENCE	26.40	11.70	25.70	11.40	26.70	11.70	25.90	11.90
COLLEGE	0.51	0.50	0.51	0.50	0.51	0.50	0.50	0.50
DEALER	0.66	0.48	0.61	0.49	0.67	0.47	0.65	0.48
FARMER	0.24	0.43	0.21	0.41				
LABEL					0.79	0.41	0.80	0.40
MAGAZINE					0.41	0.49	0.38	0.49
MSDS					0.24	0.43	0.25	0.44
MSU					0.48	0.50	0.53	0.50
PAPER					0.14	.034	0.15	0.36
CARCIN					0.56	0.50	0.53	0.50
HEALTH							0.78	0.30
LEACH	0.41	0.49	0.46					
CONTAMINATED	0.02	0.14	0.01	0.12	0.01	0.12	0.01	0.08
PRICEDIFFERENCE	1.89	1.82	1.32	1.51	1.84	1.79	1.32	1.47

Table 3.2 - (cont'd)

	Fish-Safe Formulation			
	Entire Sample (N=313)		Purchasers (N=90)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
ADOPTF	0.29	0.45	1.00	0.00
ACRES APPLIEDF	37.00	119.20	128.80	194.70
ACRES APPLIED TY			166.00	322.00
HOURSWORK	16.10	22.20	20.20	23.50
INCOME	44,600	27,000	43,900	26,900
LIVESTOCK	19.80	30.60	17.80	28.50
ACRESCORN	199.00	309.00	195.00	389.00
RESIST	0.47	0.50	0.57	0.50
IRRIGATE	3.58	15.32	2.44	11.02
WEED PRESSURE	0.75	0.44	0.72	0.45
USE NEAR	0.66	0.47	0.79	0.41
EXPERIENCE	26.00	11.30	22.10	9.80
CHILDREN	0.50	0.50	0.53	0.50
COLLEGE	0.54	0.49	0.54	0.50
CONSULTANT	0.16	0.36	0.12	0.34
FARMER	0.22	0.42	0.21	0.41
LABEL	0.80	0.40	0.82	0.38
PAPER	0.13	0.33	0.16	0.36
SALESMAN	0.25	0.44	0.24	0.43
FISH	0.42	0.50	0.50	0.50
FISHM	0.05	0.22	0.08	0.27
FISHTOX	0.57	0.50	0.63	0.48
PRICEDIFFERENCE	1.89	1.82	1.36	1.52

Table 3.3 - 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)

	Next Year (N=147)		*Three Years (N=146)*	
Variable	Estimate	P-Value	Estimate	P-Value
CONSTANT	-274.21	0.00	-183.21	0.00
INCOME	1.30	0.01	.59	0.08
LIVESTOCK	-0.65	0.22	-0.49	0.13
ACRESCORN	0.81	0.00	0.80	0.00
NOTILL	0.96	0.01	0.56	0.02
USENEAR	102.92	0.02	80.58	0.00
CHILDREN	17.76	0.54	43.56	0.03
COLLEGE	-103.18	0.00	-51.93	0.01
CONSULTANT			-31.18	0.21
DEALER	66.73	0.04	52.26	0.02
FARMER	-58.70	0.13	-23.73	0.35
LABEL			33.49	0.17
CONTAMINATED	42.06	0.63	85.88	0.16
PRICEDIFFERENCE	-6.39	0.55	1.79	0.80
σ	102.61		80.84	

Summary Statistics	**Adoption**	**Consumption Next Year**	**Consumption Three Years**
	LRI=.18 Adoption prediction rate=.694 Non-adoption prediction rate=.669	-Log likelihood=765	-Log likelihood=744

Table 3.4 - 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)

	This Year (N=163)		*Three Years (N=163)*	
Variable	Estimate	P-Value	Estimate	P-Value
CONSTANT	-285.96	0.00	-217.86	0.00
ACRESCORN	0.86	0.00	0.96	0.00
ATRAZINE95	58.55	0.22	77.60	0.13
RESIST	32.39	0.12	20.38	0.26
USENEAR	64.30	0.04	44.76	0.10
UNTREATED WATER	52.34	0.18	15.26	0.62
LIVESTOCK	-0.34	0.33	0.07	0.81
COLLEGE	-58.31	0.01	-20.72	0.26
DEALER	32.52	0.16	10.48	0.60
LABEL	45.43	0.12	66.41	0.01
MSDS	-30.33	0.24	-27.66	0.21
CARCIN	-24.11	0.25	-26.18	0.15
CONTAMINATED	81.24	0.39	17.51	0.84
HEALTH	49.28	0.06	2.39	0.91
PRICEDIFFERENCE	-9.11	0.30	-2.70	0.70
σ	85.90		79.46	

Summary Statistics	**Adoption**	**Consumption Next Year**	**Consumption Three Years**
	LRI=.14 Adoption prediction rate=.714 Non-adoption prediction rate=.693	-Log likelihood=849	-Log likelihood=820

Table 3.5 - 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 fish-safe atrazine formulation (Truncated)

	This Year (N=90)		*Three Years (N=88)*	
Variable	Estimate	P-Value	Estimate	P-Value
CONSTANT	-85.07	0.27	65.54	0.13
HRSWORK	0.65	0.34	0.36	0.24
LIVESTOCK	-1.92	0.01	-0.80	0.00
ACRESCORN	0.52	0.00	0.88	0.00
IRRIGATE	4.67	0.00	0.75	0.21
NOTILL			-0.24	0.17
WEED PRESSURE			-20.57	0.15
USENEAR	49.48	0.27	-16.03	0.32
CHILDREN	58.60	0.10	27.66	0.08
EXPERIENCE			-1.82	0.04
COLLEGE	-111.41	0.00	-20.26	0.14
CONSULTANT	-65.14	0.13	-34.41	0.07
FARMER	-97.56	0.04	-35.51	0.04
LABEL	71.80	0.09	25.03	0.17
PAPER			-22.14	0.14
SALESMAN	84.92	0.03	-14.05	0.34
FISH			-4.05	0.33
FISHM	-53.69	0.36	14.71	0.56
PRICEDIFFERENCE	-16.90	0.15	-0.36	0.93
σ	95.51		45.86	

Table 3.5 (cont'd)

Summary Statistics	**Adoption**	**Consumption Next Year**	**Consumption Three Years**
	LRI=.12 Adoption prediction rate=.278 Non-adoption prediction rate=.924	-Log likelihood=484	-Log likelihood=432

Chapter 4

FARMER WILLINGNESS TO PAY FOR HERBICIDE SAFETY CHARACTERISTICS[13]

Introduction

Agricultural pesticide use can have a variety of adverse effects on the environment, including contamination of groundwater and surface water, chronic and acute health effects in humans, fishery losses, as well as adverse effects on other forms of wildlife. Groundwater impacts are particularly important as over 50 percent of Americans and 90 percent of rural U.S. households and obtain drinking water from wells (Pimentel et al., 1992; Jordan and Elnagheeb, 1993). The Environmental Protection Agency estimates that 446,000 rural domestic wells contain levels of one of more pesticides above their Maximum Containment Levels (EPA, 1990). Exposure to pesticides has been linked to numerous health problems such as lymphatic and reproductive tract cancer, Hodgkin's disease, leukemia, and infertility (Blair et al., 1985; Colborn et al., 1993). Runoff of pesticides into aquatic environments has been estimated to cause 6 to 14 million fish to be killed annually (Pimentel et al., 1992). Finally,

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[13]Portions of the theoretical model appeared earlier as: Owens, N., S. Swinton, and E. van Ravenswaay. "Farmer Demand for Safer Pesticides." Staff Paper No. 95-27, Department of Agricultural Economics, Michigan State University, East Lansing, MI. 1995.

exposure to pesticides has impaired reproduction in several species of wildlife including alligators and Western gulls (Hileman, 1994).

In response to health and environmental concerns, a variety of regulations have been adopted; including the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). In addition, the Environmental Protection Agency may initiate Special Review of pesticides and currently requires that pesticides approved before 1985 undergo a re-registration process in which it is determined whether their continued use will be permitted. Yet to develop more effective pesticide policies that address health and environmental concerns, and perhaps reduce farm pesticide use, policy makers need to understand more about farmers' willingness to self regulate out of concern for their health and/or the environment. However, at this time no reliable information on farmer willingness to pay for health and environmental quality exists.

Much recent research has attempted to estimate how much the general public is willing to pay for different groundwater programs as well as for increased health and/or reduced risk of death (Fisher, Chestnut, and Violette, 1992; Schultz and Lindsey, 1990; Abdalla et al., 1992; Jordan and Elnagheeb; Loehman, Park, and Boldt, 1994). One recent study estimated the general public's willingness to pay to reduce risks from agricultural pesticide use (Mullen, Norton, and Reaves, 1997). Little effort, however, has been devoted to farmers and farm households. Results from recent studies indicate that farmers are concerned about and are willing to pay to protect their health and groundwater resources from pesticide contamination (Higley and Wintersteen, 1992; Beach and Carlson, 1993).

This paper estimates a demand model and computes farmer willingness to pay for risk reduction arising from use of three specific safety characteristics of herbicides. Briefly, this is accomplished by offering farmers the choice between regular atrazine or a hypothetical formulation of atrazine differing from regular atrazine by only one safety characteristic. Three safety characteristics are examined - leaching potential, carcinogenicity, and fish toxicity.

The remainder of the paper is organized in the following manner. First, a theoretical model of farmer willingness to pay for reductions in risk associated with pesticide safety characteristics is developed. The model is used to make inferences about farmer willingness to pay for reductions in pesticide health and/or environmental quality risk. Second, the econometric method used to estimate demand and willingness to pay is presented. The third section discusses the data utilized. Finally, estimates of willingness to pay and conclusions are presented.

Theoretical Model

Freeman (1993) introduced a life-cycle model of willingness to pay for a change in the probability of death. In it he posited that an individual's utility depends only on consumption and leisure. Expanding on this, consider an individual currently *j* years of age who derives utility from consumption X_t, leisure, L_t, health, H_t, and environmental quality, V_t:

$$U(X_t, L_t, H_t, V_t).$$

It is assumed that each of these attributes increases utility. Thus,

$$\partial U/\partial X_t \geq 0$$
$$\partial U/\partial L_t \geq 0$$
$$\partial U/\partial H_t \geq 0$$
$$\partial U/\partial V_t \geq 0.$$

Health is produced via a health production function and is affected by exposure to a pesticide, $E(\rho_t)$, where ρ_t represents the quantity and toxicity of the pesticide used. An increase in pesticide quantity and/or toxicity leads to increased exposure. Increased exposure decreases health. The individual is able to undertake averting activities such as purchasing bottled water, α_t, in order to avoid and or reduce his/her exposure. The individual's initial health endowment is represented by H^0 and he/she may also undergo medical treatments, m_t, which mitigate the affects of exposure. In order to make the model more tractable, the levels of averting expenditures and medical treatments have not been made functions of pesticide quantity or toxicity:

$$H(E(\rho_t, \alpha_t), m_t; H^0).$$

The following relationships hold:

$$\partial E/\partial \rho_t \geq 0$$
$$\partial E/\partial \alpha_t \leq 0$$
$$\partial H_t/\partial E \leq 0$$
$$\partial H_t/\partial m_t \geq 0.$$

Environmental quality is assumed to be a function of pesticide quantity and toxicity, as well as other factors beyond the control of the individual, Z_t, such as weather:

$$V_t(\rho_t, Z_t).$$

As pesticide use has been linked to negative environmental impacts (Edwards, 1993; Hileman, 1994), a negative relationship between environmental quality and pesticide use is assumed.

$$\partial V_t / \partial \rho_t \leq 0$$

Let $P_{j,t}$ represent the probability an individual of age *j* dies at age *t* just before his/her *t+1* th birthday. $P_{j,t}$ can also be though of as the probability he/she lives *t-j* more years. As is the case with all probabilities, the following hold:

$$P_{j,t} \geq 0,\ t = j, j+1, \ldots T$$
$$\sum_{t=j}^{T} P_{j,t} = 1,$$

where *T* is the individual's maximum attainable age.

Let $q_{j,t}$ represent the probability the individual survives to his/her *t* th birthday, given he/she is alive at age *j*. This is also the probability he/she dies at age *t+1* or later. This survival probability is a function of the same arguments as health: $E(\rho_t, \alpha_t)$, m_t, and

H^0. Thus, actions that improve health also influence survival probability. For example, if a safer pesticide to humans is used, not only will the individual experience decreased health risk, but also he/she will have a greater chance of surviving each subsequent year:

$$q_{j,t} = \sum_{s=t+1}^{T} P_{j,s}$$
$$q_{j,t}(E(\rho_t, \alpha_t), m_t; H^0).$$

Let d_t be the probability of dying at age t conditional on being alive at the beginning of that year. Thus, the conditional probability of surviving that year is $1-d_t$. The following is also true:

$$1 - d_t = \frac{q_{j,t}}{P_{j,t}}.$$

Expected lifetime utility at age j, $E(U_j)$ is the sum of the utility from living each of T-j more years times the probability of doing so and is given by the following:

(4.1) $$E(U_j) = \sum_{t=j}^{T} q_{j,t} (1+r)^{j-t} U(X_t, L_t, H_t, V_t),$$

where r is the discount rate and is assumed to be the same as the interest rate. It is also assumed that utility is additively separable and there is no bequest motive.

The production function is an expanded version of the Lichtenberg and Zilberman (1986) model of damage control and is represented by the following:

$$Q(G(\rho_t), N_t, I_t, \iota_t),$$

where Q represents output and $G(\rho_t)$ is a damage abatement function. The production function is based on the idea that damage control agents (of which pesticides are one) affect output differently than do other inputs (hours worked on farm by both the individual, N_t, and hired labor, ι_t, and other productive inputs, I_t). Rather than increasing potential output as do N_t, ι_t, and I_t pesticides increase the share of potential output that producers realize by reducing damage from pests (Lichtenberg and Zilberman, 1986). Pesticides are but one of the damage control agents used on farms.

Lichtenberg and Zilberman (1986) characterize output as a combination of potential output and losses caused by pests. Losses of output depend on both environmental conditions (i.e., weather) and the pesticide used. The productivity of the pesticide is defined in terms of its contribution to damage abatement services. A pesticide is considered productive if it is able to abate damage caused by the pest. Therefore, an abatement function $G(\rho_t)$, is defined as the proportion of the destructive capacity of the pest eliminated by the application of the pesticide. Following Lichtenberg and Zilberman, $G(\rho_t)$ is defined on the (0,1) interval. When G=1, the destructive capacity of the pest is completely eliminated, output is the maximum that can be attained given the combination of other inputs used. When G=0, the destructive capacity of the pest is at its maximum. Finally, the abatement function is monotonically increasing and approaches 1 as use of the pesticide increases. Thus, the production function is characterized as a function of labor, other productive inputs, and damage abatement. When the destructive capacity of the pest is eliminated, output is indicated as

$$Q(1, I_t, N_t, \iota_t).$$

It is assumed that pest damage does not affect product quality (as is the case with most grain crop pests).

Annual earnings, Y_t, is of the form revenue minus expenses, where expenses include health care, averting activities, pesticides, other productive inputs, and hired labor:

$$Y_t = R_t Q(G(\rho_t), I_t, N_t, \iota_t) - C_{m_t} m_t - C_{\alpha_t} \alpha_t - C_{\rho_t} \rho_t - C_{I_t} I_t - \iota_t w_t + c. \qquad (4.2)$$

Where,

R	is the unit price of output
Q	is output
w	is the hourly wage paid to farm workers
C_m	is the unit cost of medical treatments and mitigating activities
C_a	is the unit cost of averting and avoidance activities
C_p	is the unit cost of the pesticide
C_I	is the unit cost of other productive inputs
c	is a constant term.

The individual's budget constraint can be expressed as the requirement that the present value of expected consumption equal initial wealth,μ, plus the present value of lifetime earnings and is represented by the following (again, assuming no bequest motive).:

$$\sum_{t=j}^{T} q_{j,t}(1+r)^{j-t}X_t = \sum_{t=j}^{T} (q_{j,t}(1+r)^{j-t}Y_t) + \mu. \tag{4.3}$$

Here the price of X_t is normalized to a unit value.

The individual's problem is to maximize expected lifetime utility, equation (4.1) :

$$Max \sum_{t=j}^{T} (1+r)^{j-t} q_{j,t} U(X_t, L_t, H_t, V_t)$$

subject to the budget constraint, equation (4.3):

$$\sum_{t=j}^{T} ((1+r)^{j-t} q_{j,t} Y_t) + \mu - \sum_{t=j}^{T} ((1+r)^{j-t} q_{j,t} X_t) = 0$$

as well as a time constraint:

$$\tau - L_t - N_t = 0.$$

In each period, the individual divides his/her time between working on the farm and leisure. The amount of time available in each period does not vary and is represented by τ.

Formally the lagrangian is the following:

$$\begin{aligned} \mathcal{L} &= \sum_{t=j}^{T} (1+r)^{j-t} q_{j,t}\, U(X_t, L_t, H_t, V_t) \\ &+ \lambda_1 [\sum_{t=j}^{T} ((1+r)^{j-t} q_{j-t} Y_t) + \mu - \sum_{t=j}^{T} ((1+r)^{j-t} q_{j-t} X_t)] \\ &+ \lambda_2 [\tau - L_t - N_t]. \end{aligned} \tag{4.4}$$

Here, λ_1 and λ_2 are lagrangian multipliers.

The above model can be used to make inferences about farmer willingness to pay for pesticide safety characteristics and thus reductions in risk. Consider a hypothetical pesticide that has the same efficacy as the one currently used (the abatement function is not affected), but differs by one safety characteristic (toxicity to humans, animals, or some aspect of the environment). The only difference between the original pesticide used and the hypothetical pesticide is the one safety characteristic. Assume that it is possible to measure health as a continuous variable. In addition, assume that pesticide attributes such as safety can also be measured as continuous variables.

The individual's marginal willingness to pay at age j, for a reduction in risks arising from the safety characteristic, $wtp_{d\rho}$ - the change in the toxicity, can be expressed as (Freeman, 1993):

$$wtp_{d\rho} = \frac{dC_{\rho_t}}{d\rho_t} = \frac{d\mathcal{L}/d\rho_t}{d\mathcal{L}/dC_{\rho_t}}.$$

Here dC_p, the change in the unit cost of the pesticide (from the one currently used to the safer) can be thought of as the price of the safety characteristic (or of risk reduction).

Marginal willingness to pay for a reduction in risks to humans associated with the safety characteristic (environmental quality risks are unchanged) can then be expressed as:

$$wtp_{health} =$$

$$(4.5) \quad -\frac{\sum_{t=j}^{T}(1+r)^{j-t}\left(\frac{\partial q_{j,t}}{\partial E}\right)\left(\frac{\partial E}{\partial \rho_t}\right)\left(U(X_t, L_t, H_t, V_t) + \lambda_1 (Y_t - X_t)\right)}{\lambda_1 \sum_{t=j}^{T}(1+r)^{j-t} q_{j,t}\, \rho_t} - \frac{\sum_{t=j}^{T}(1+r)^{j-t} q_{j,t}\left(\left(\frac{\partial U}{\partial H_t}\left(\frac{\partial H_t}{\partial E}\right)\left(\frac{\partial E}{\partial \rho_t}\right) - \lambda_1 C_{\rho_t}\right)\right.}{\lambda_1 \sum_{t=j}^{T}(1+r)^{j-t} q_{j,t}\, \rho_t}.$$

It should be noted that the above is always non-negative. This expression for willingness to pay can be divided into two parts. The first part, the top half of the expression, can be thought of as a length of life effect. The new safety characteristic increases length of life by reducing exposure. This reduced exposure lengthens life, or at least the probability he/she survives to each subsequent birthday. The second part, the bottom half of the expression, can be thought of as a quality of life effect. The reduced exposure also decreases health risk, which in turn, increases the individual's utility. The reduced exposure also decreases health risk, which in turn, increases the individual's utility.

Similarly, marginal willingness to pay for a reduction in risks to the environment (human health risks are unchanged) is given by the following:

$$wtp_{env} =$$

(4.6)
$$-\frac{\sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}((\frac{\partial U}{\partial V_t})(\frac{\partial V_t}{\partial \rho_t}) - \lambda_1 C_{\rho_t})}{\lambda_1 \sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}\rho_t}.$$

Again, this expression of willingness to pay is always non-negative. This is comparable to the second half of the wtp_{health} expression. This increase in environmental quality increases the individual's utility (quality of life).

Finally, marginal willingness to pay for a reduction in risks to both human health and the environment is given by the following:

$$wtp_{health,env} =$$

(4.7)
$$-\frac{\sum_{t=j}^{T}(1+r)^{j-t}((\frac{\partial q_{j,t}}{\partial E})(\frac{\partial E}{\partial U})(U(X_t, L_t, H_t, V_t) + \lambda_1(Y_t - X_t)))}{\lambda_1 \sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}\rho_t}$$
$$-\frac{\sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}((\frac{\partial U}{\partial H_t})(\frac{\partial H_t}{\partial E})(\frac{\partial E}{\partial \rho_t}) + (\frac{\partial U}{\partial V_t})(\frac{\partial V_t}{\partial \rho_t}) - \lambda_1 C_{\rho_t})}{\lambda_1 \sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}\rho_t}.$$

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.[14] This is illustrated graphically for the non-leaching attribute in Figure 4.1.

Total willingness to pay for X(0) acres of source reduction in leaching risks from atrazine is the area $P_{max}X(0)0$. Mean willingness to pay per acre of risk reduction is then this area divided by X(0). Similarly, total willingness to pay for $X(P_a)$ acres of source reduction in leaching risks from atrazine is the area $P_{max}aX(P_a)0$. Mean willingness to pay is $P_{max}aX(P_a)0$ divided by $X(P_a)$. Clearly, total willingness to pay increases as quantity increases, while mean willingness to pay decreases. Marginal willingness to pay for the $X(P_a)$th acre of risk reduction from leaching risks of atrazine is P_a.

In order to estimate willingness to pay, estimating a demand curve for each of the attributes 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

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[14]The most correct measurement of willingness to pay is the area to the left of the Hicks-compensated demand curve, not the Marshallian demand curve. However, it is the Marshallian demand curve, not the Hicks, that is observable. This may suggest that measures of willingness to pay based on the observed Marshallian demand curve are flawed. However, Willig (1976) and Freeman (1993) found that the difference between willingness to pay calculated using both demand curves is extremely small.

the attribute to use (the consumption decision). In the case of use of a pesticide, a random sample of farmers would reveal a number of individuals who have not adopted and thus do not use any of the pesticide (or the attribute). Accordingly, it is important to know the factors which determine both adoption and consumption.

The Cragg double-hurdle model (1971) can be used to explicitly model this two-stage decision making process. The double hurdle takes the form:[15]

$$\begin{aligned} y_i &= 0 \quad \text{if } w_i^* \leq 0 \\ y_i &= 1 \quad \text{if } w_i^* > 0 \end{aligned}$$

where,

$$w_i^* = B_2 z_{2i} + v_i.$$

Conditional on $w_i^* > 0$,

$$\begin{aligned} \rho_i &= B_1 z_{1i} + u_i \quad \text{if } B_1 z_{1i} + u_i > 0 \\ \rho_i &= 0 \quad \text{if } B_1 z_{1i} + u_i \leq 0. \end{aligned}$$

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 $N(0, \sigma^2_v=1)$, 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

[15]The presentation of the Cragg model borrows heavily from Bockstael et al. (1990).

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 likelihood function is given by

$$\prod_{i \in n} \Phi(-B_2 z_{i2}) \prod_{i \in a} \Phi(B_2 z_{i2}/\sigma_u)\sigma_u \phi(y_i/\sigma_u - B_1 z_{i1}/\sigma_u)/\Phi(B_1 Z_{i1}). \tag{4.8}$$

Where n is the subset of non-adopters and a is the subset of adopters. In addition, Φ and ϕ are the cumulative distribution function and the probability density function of the standard normal. 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:

$$E(x_i) = \Phi(\hat{B}_2 z_{2i})(\hat{B}_1 z_{1i} + \sigma_u (\phi(\hat{B}_1 z_{1i}/\sigma_u)/\Phi(\hat{B}_1 z_{1i}/\sigma_u))). \tag{4.9}$$

Data Source

The data used in this study comes from a survey of Michigan corn growers conducted by Owens, Swinton, and van Ravenswaay (1997). The survey had an overall response rate of 54 percent, including 656 respondents (35 percent) who both used herbicides and grew corn. Respondents to the survey were asked in 1995 to consider whether they would use, in 1996, regular atrazine or a hypothetical alternative atrazine formulation differing from regular atrazine by only one safety characteristic. Three safety characteristics were examined; leachability, carcinogenicity, and fish toxicity. Atrazine was chosen because of its familiarity to farmers; over 65 percent of U.S. corn acreage is treated with atrazine (Ribaudo and Bouzaher, 1994). 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. 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 at specified prices and market conditions. 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 survey sample was partitioned so that each respondent faced a choice on only one price pair. Respondents were asked whether they would use, in 1996, the "new" formulation at the stated prices and, if so, on how many acres this formulation would be applied.

Respondents also answered questions about 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. 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. In addition, it can be argued that a variety of factors may shift the corn production function. For example, those with many years of farming experience may be on a different production function than new farmers. Thus, questions on factors possibly influencing production were included.

Two previous studies attempted to measure willingness to pay to avoid various risks associated with pesticide use. Higley and Wintersteen (1992) surveyed field crop producers to elicit willingness to pay for reductions in environmental impacts of pesticide applications. Their results do indicate that producers are willing to pay an average of $5.79 to avoid "low risk" and $12.91 to avoid "high risk" from a single application of insecticide. Mullen, Norton, and Reaves (1997) conducted a survey of the general public and found that willingness to pay to avoid "high risk" of acute human health effects was $4.28 per month, yet willingness to pay to avoid "high risk" of damage to avian species was $4.17 per month.

While these results are provocative, the survey methods utilized, and therefore the data collected and ultimately the results obtained suffer from several deficiencies which were addressed by Owens, Swinton, and van Ravenswaay (1997). First, the two previous surveys likely suffered from nonresponse bias; the response rate to the Higley and Wintersteen (1992) survey was 22 percent, while Mullen, Norton, and Reaves (1997) survey had a response rate of 17 percent. As stated previously the response rate to the Owens, Swinton, and van Ravenswaay (1997) survey was 54 percent.

Another source of potential error arises from the open-ended willingness to pay questions of both Higley and Wintersteen (1992) and Mullen, Norton and Reaves (1997). Hoehn and Krieger (1988) stress that an accept-reject, fixed cost elicitation procedure, utilized by Owens, Swinton, and van Ravenswaay (1997) tends to generate more reliable results. Finally, Higley and Wintersteen (1992) as well as Mullen, Norton, and Reaves (1997) merely asked what respondents would be willing to pay to avoid "high risks" to the environment or human health, yet no definition of "high risks" was provided. In both of these surveys, no information was elicited on how harmful respondents believed pesticides to be to various aspects of the environment (i.e., fish, humans, groundwater, etc). Rather, respondents were merely asked how important it was to reduce risks from pesticides to various categories. When asked in this way, respondents are likely to indicate that most things are important, potentially biasing the results. The Owens, Swinton, and van Ravenswaay (1997) survey elicited information on specific, clearly defined aspects of health and environmental quality.

The above studies make some effort to provide a broad based measure of willingness to pay for environmental quality. However, the clearly defined context along with the high response rate and closed-ended willingness to pay questions of Owens, Swinton, and van Ravenswaay (1997) allows more accurate measurement of willingness to pay, albeit for more specific components of health and environmental quality.

Results

As previously discussed, the new herbicide formulations were described as identical to regular atrazine with the exception of one safety characteristic. When asked to consider use of the new formulations, respondents were provided with prices for both regular atrazine and the new formulations. This information can be looked at in two distinct ways. First, the demand for the hypothetical formulation can be considered. Here the demand equation can be conditioned on, among other things, own price (the price of the new formulation) and the price of a substitute (the price of regular atrazine). Alternatively, one can consider demand for the safety characteristic alone. 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.[16] Thus, one can also estimate the demand function for the safety characteristic.

A definition of variables used in the double-hurdle demand estimations are presented in Table 3.1, while the descriptive statistics of these variables are presented in

[16]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.

Table 3.2. Tables 3.3 through 3.5 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.

Other variables proving to be influential in the adoption portion of the double-hurdle demand estimation included acres of corn (ACRESCORN), farming experience (EXPERIENCE), and the belief that most nearby farms use atrazine (USENEAR). For the non-leaching and non-carcinogenic formulations, those with larger farms were less likely to adopt, however this variable had no influence on adoption of the fish-safe formulation. For all three formulations, EXPERIENCE negatively influenced adoption. The negative coefficient on USENEAR, provides some evidence that farmers try to compensate for atrazine use of neighboring farms.

The sources of information upon which farmers relied for the health and environmental effects of herbicides also proved to be important although no clear pattern emerges. For example, in the non-leaching equation, reliance on dealers reduced the probability of adoption, while in the non-carcinogenic equation, reliance on Michigan State University Extension enhanced the probability of adoption. In the non-leaching equation, risk perceptions proved to be important; those agreeing with scientific evidence concerning atrazine's leaching potential were more likely to adopt. Adoption of the fish-safe formulation was positively influenced by the presence of fish.

In addition to the price variable, other variables proving to be influential in the consumption portion of the double-hurdle demand estimation included ACRESCORN, USENEAR, and post high school education (COLLEGE). The positive coefficient on ACRESCORN in the consumption decision indicates that although those with larger farms tend to be less likely to adopt, once this decision has been made, use increases with acreage. Again, the positive coefficient on USENEAR indicates farmers may try to compensate for the chemical use decisions of their neighbors. The estimated coefficient on COLLEGE is negative in each of the three consumption equations, this result combined with the negative coefficient on EXPERIENCE in the adoption equations suggest that those with experience and post high school education may feel they are more able to target use of hazardous chemicals and only need to use these in the most vulnerable areas of the farm (if at all).

As with the adoption decisions, sources of information proved to be important in determining consumption of the three formulations. Reliance on chemical dealers increased consumption of the non-leaching and non-carcinogenic formulations. Reliance on other farmers for information tended to decrease consumption of the fish-safe and non-leaching formulations. For a more complete description of the double-hurdle results, see Chapter 3.

Three measures of willingness to pay were calculated for each of the safety attributes, total willingness to pay, mean willingness to pay, and marginal willingness to pay. These measures were calculated using the mean values of the dependent variables from the double-hurdle demand equations for the safety characteristics.[17] The result is the average respondent's demand. The area under the demand curve for different prices and quantities can then be calculated (see Figure 4.1). This measure of willingness to pay is the average respondent's total willingness to pay for source reduction in risks from atrazine for 1996. Mean willingness to pay per acre of risk reduction (again for 1996) can then be calculated by dividing by the appropriate quantity (again, see Figure 4.1).[18] The results of the willingness to pay estimation are presented in Tables 4.1 through 4.3.

As illustrated in Figure 4.1, total willingness to pay increases as quantity increases, while mean and marginal willingness to pay decreases for all three safety characteristics. The average respondent's mean willingness to pay 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 willingness to pay 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

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[17]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 $B_2 z_2$ in the calculation of the Cragg demand function. A similar procedure is followed for the consumption decision (the B_1 component).

[18]When calculating willingness to pay (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.

reduction. Compared with a baseline price for atrazine of $3.00 per acre, these figures represent an average willingness to pay of more than 100 percent more for these two safety attributes.

Cancer is a catastrophic and, in many cases, fatal human health effect. Therefore one might expect that willingness to pay for reductions in carcinogenicity risks be even greater than willingness to pay 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 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 willingness to pay associated with the fish-safe characteristic is 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 willingness to pay 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 willingness to pay 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 willingness to pay 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. The regression results are presented in Tables 4.4 through 4.6. In all equations, the estimated coefficient on the price variables are all negative and highly significant.

The willingness to pay estimates provided using only price are similar to those estimated with the full set of conditioning variables (see the fifth columns of Tables 4.1 through 4.3). From Table 4.1, mean willingness to pay per acre for 40 acres of reduction in risks associated with leaching is $4.40. Mean willingness to pay per acre for 40 acres calculated using only price is $4.63. Similarly, mean willingness to pay 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 willingness to pay 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, willingness to pay 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 willingness to pay 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 as discussed in Chapter 3. 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 willingness to pay 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 willingness to pay 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

The theoretical model derived here as well as the empirical results from Beach and Carlson (1993) and Higley and Wintersteen (1992) suggest that farmers have positive willingness to pay for reductions in health and/or environmental quality risks. This research confirms this inference.

Willingness to pay for reductions in source risks associated with three safety characteristics was investigated: leaching potential, carcinogenicity, and fish toxicity. 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.

More important than confirming that farmers have positive willingness to pay, the survey methods utilized here do a more thorough job than prior efforts of investigating the factors that influence demand and willingness to pay for these three safety characteristics. As such, the estimates provided by this research are more reliable. Moreover, these estimates of willingness to pay focus on reduction in specific, measurable risks, rather than an attribute as vague and ambiguous as "health and environmental quality." The information on willingness to pay can be used to design environmental policies that protect specific aspects of environmental quality. It should be noted, however, that these results are not additive. Willingness to pay for an attribute that provides reduction in risks of cancer and to toxic to fish is not necessarily the sum of the estimates provided here. One future research challenge is to investigate more fully how willingness to pay changes with additional risk reduction characteristics.

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.

Tables and Figures

Figure 4.1 - Willingness to Pay for Reductions in Risks Associated with Atrazine Leaching

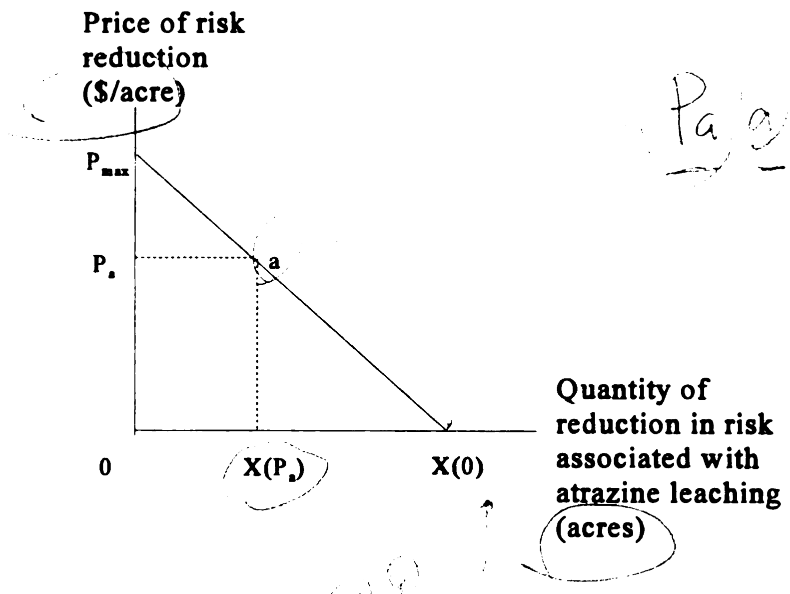

Table 4.1 - Average Respondent's Estimated Total, Mean and Marginal Willingness to Pay Associated with Non-Leaching Characteristic

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 4.2 - 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 4.3 - 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

Table 4.4 - Double Hurdle Regression Results for Non-Leaching Characteristic Using Only Price

Adoption of non-leaching attribute (Probit, N=301)			
Variable		Estimate	P-Value
CONSTANT		0.39	0.00
PRICE DIFFERENCE		-0.22	0.00
Consumption of non-leaching attribute (Truncated, N=147)			
Variable		Estimate	P-Value
CONSTANT		-829.11	0.07
PRICEDIFFERENCE		-184.96	0.01
σ		350.78	
Summary Statistics	**Adoption** LRI=.07 Adoption prediction rate=.538 Non-adoption prediction rate=.748	**Consumption** -Log likelihood=821.29	

Table 4.5 - Double Hurdle Regression Results for Non-Carcinogenic Characteristic Using Only Price

Adoption of non-carcinogenic attribute (Probit, N=352)			
Variable		Estimate	P-Value
CONSTANT		0.27	0.01
PRICE DIFFERENCE		-0.20	0.00
Consumption of non-carcinogenic attribute (Truncated, N=163)			
Variable		Estimate	P-Value
CONSTANT		-1759.30	0.00
PRICEDIFFERENCE		-245.29	0.00
σ		597.12	
Summary Statistics	**Adoption** LRI=.06 Adoption prediction rate=.503 Non-adoption prediction rate=.748	**Consumption** -Log likelihood=971.20	

Table 4.6 - Double Hurdle Regression Results for Fish-Safe Characteristic Using Only Price

Adoption of fish safe attribute (Probit, N=313)

Variable	Estimate	P-Value
CONSTANT	-0.30	0.00
PRICE DIFFERENCE	-0.15	0.00

Consumption of fish safe attribute (Truncated, N=90)

Variable	Estimate	P-Value
CONSTANT	-938.93	0.04
PRICEDIFFERENCE	-271.60	0.00
σ	459.33	

Summary Statistics	**Adoption** LRI=.03 Adoption prediction rate=.00 Non-adoption prediction rate=1.00	**Consumption** -Log likelihood=529.50

Chapter 5
CONCLUSIONS AND POLICY IMPLICATIONS

The goals of this research were to investigate the factors motivating the use of safer pesticides and to estimate farmer demand and willingness to pay for reductions in risks associated with the use of three herbicide safety characteristics: leaching, carcinogenicity, and fish-safety. To this end, a survey of Michigan corn farmers was conducted. The survey was carefully designed to ensure valid results. Farmers were offered the choice of purchasing hypothetical atrazine formulations over actual atrazine.

An important aspect of the survey was that the hypothetical formulations differed from atrazine by only one of the safety characteristics. Because of the high rate of atrazine use by corn farmers, this approach assured that respondents had a clear understanding of the new formulations. Another important aspect of the survey design was the procedure used to elicit willingness to pay. Rather than asking respondents how much they would pay for each of the new formulations, the survey asked whether and how much of the new formulations would be utilized at specified prices and market conditions. These responses were then used to estimate demand and willingness to pay. This accept-reject choice is what farmers actually face when making herbicide use decisions. Thus the market scenario was designed to be plausible, understandable, and realistic.

Results from the survey indicate that farmers tend to be unaware of many of the health and environmental effects associated with atrazine use. This finding was rather surprising due to the high use of and familiarity with atrazine, which is used on over 65 percent of U.S. corn acreage (Ribaudo and Bouzaher, 1994). Less than 60 percent knew that atrazine has a high probability of leaching and fewer than half of respondents were familiar with any of the other health and environmental effects listed in the survey. Respondents often doubted the validity of these health and environmental effects. Results also indicate that the chemical label and herbicide dealer were the most frequently used sources for information on the health and environmental effects of atrazine. Together these results seem to suggest that the label and dealer are not effectively communicating the crucial health and environmental information necessary for farmers to make informed herbicide use decisions. Results also show that those utilizing Michigan Statue University Extension were more likely to be familiar with the cancer, leaching, and half-life characteristics of atrazine than those relying on the chemical label and dealer.

Results from the demand estimation indicate that a variety of factors influence adoption and use of the alternative atrazine formulations, and thus the safety characteristics. Price was a key variable. In addition, characteristics such as corn acreage, farming experience, and education also proved to be important. Knowledge of the factors influencing adoption and consumption of these safer formulations could potentially be used to increase adoption and intensity of use of other safer pest control methods. Sources of information proved to be influential in the adoption and consumption equation for all three safety characteristics. While no clear pattern emerged, dealers, chemical labels, newspapers, and other farmers were influential information sources. Finally, knowledge of atrazine's leaching potential proved to be influential in the decision to adopt the non-leaching formulation.

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.

The empirical findings presented here have important policy implications. The descriptive statistics suggest that herbicide labels do not clearly communicate health and environmental information. Clearly, much effort has been spent ensuring that product labels indicate proper methods of use and disposal as well as precautions need to prevent harm to humans, animals, and the environment. However, both researchers and policy makers also need to ensure that this important health and environmental information is communicated in a way that farmers notice, understand, and believe.

Farmers clearly are concerned about health and environmental quality and are willing to self-regulate their use of herbicides. This willingness can and should be utilized by policy makers. Flexible agricultural policies are preferable to the command-control approaches currently utilized by policy makers are preferable. Farmer willingness to self-regulate can be utilized by policy makers in at least two ways. First, these estimates of willingness to pay can be interpreted as implicit environmental input costs. As such, they can be factored into integrated pest management strategies as "environmental thresholds" (Higley and Wintersteen, 1992). Consider the non-leaching attribute. Pesticide fate and transport models could be used to predict the amount of atrazine leaching under various scenarios. When the willingness-to-pay estimates are considered implicit costs of leaching, they can be used with the fate and transport information to augment profitability-based economic thresholds.

Second, the results presented here suggest that providing farmers with clearly stated, understandable information on the health and environmental risks of herbicides would allow them to make more informed herbicide choices. Health and environmental information is available to farmers; however this research reveals that many farmers are still not familiar with many of the health and environmental effects of herbicides. In the absence of a clear understanding of these effects, it is impossible for farmers to carefully consider health and environmental risks when making herbicide use decisions. A future challenge for researchers and government is to design more user friendly methods of risk communication. This research shows that farmers are concerned about health and environmental quality; they are just not getting the information necessary to integrate these concerns into their weed control practices. While the results provided some links with sources of information, more complete research is needed to more fully capture the relationship between sources of information and willingness to pay.

This research also highlights the need for further investigation of farmers' knowledge of the health and environmental risk of agricultural chemicals. These and other results provide empirical evidence that willingness to pay increases with knowledge and concern about environmental risks. However, a challenge to researchers is to develop measures that more accurately reflect knowledge and perceptions about environmental risks. For example, it would be helpful to learn more about how farmers perceive their own risk of the health and environmental effects detailed in this study.

All of the willingness-to-pay estimates provided in this study are for single aspects of health and environmental quality. There are a myriad of additional aspects of environmental quality yet to be studied. In addition to estimating willingness to pay for additional individual health and environmental risk reduction characteristics, an effort should be made to discover how willingness to pay changes with the addition of one or more health or environmental characteristics.

This research provides important information for use in the design of more effective, flexible agricultural policies. In using the knowledge that farmers are willing to self regulate, the move to more “perfect” policies be made.

APPENDICES

APPENDIX A

Appendix A

Survey Instrument -
Corn Herbicide Choice in Michigan

1.	Did you plant corn this year? (Please circle number of your answer.)	1. YES 2. NO
2.	Did you use herbicides on any corn you planted this year? (Please circle number of your answer.)	1. YES 2. NO

If you answered NO to either of the two questions above, you do not need to continue filling out this questionnaire. Please return it in the envelope provided. Thank you for your time.

3.	How many acres of tillable land are you farming this year, including set aside? (Please write in number of acres.)	_______ACRES
4.	How many of the acres that you farm are planted with corn this year? (Please write in number of acres.)	_______ACRES
5.	What percentage of the soil in your corn fields is sandy to sandy loam in texture? (Please write in percent.)	_______%
6.	What percentage of your corn fields were irrigated this year? (Please write in percent.)	_______%
7.	Over the last five years, how would you describe the weed pressure in your corn fields? (Please circle number of your answer.)	1. SLIGHT 2. MODERATE 3. SEVERE

8. On what percentage of your corn acreage do you practice no-till? (Please write in percent.) ________ %

9. What percentage of your corn acreage has been in corn for two years or more? (Please write in percent.) ________ %

10. In recent years, have you noticed any weeds on your corn acreage that are resistant to atrazine? (Please circle number of your answer.)
    1. YES
    2. NO

11. The table below gives a list of herbicides containing atrazine that may be used on corn. Please fill in the formulation, rate of use, and number of acres for any chemicals you used on **fields planted with corn** this year. (Please write in formulations, rates, and acres.)

TRADE NAME	FORMULATION	RATE OF USE (FORMULATED PRODUCT IN UNITS PER ACRE)	NUMBER OF ACRES ON WHICH CHEMICAL WAS APPLIED
Example ABC HERBICIDE	4L	2.4 qt/Acre	175
ATRAZINE			
BICEP			
BICEP LITE			
BICEP II			
BUCTRIL-ATRAZINE			
BULLET			
GUARDSMAN			
HARNESS XTRA			
LADDOK			
LARIAT			
MARKSMAN			
SHOTGUN			
SURPASS 100			
SUTAZINE			
OTHER (Please list)			

12. Have you used atrazine on corn before this year? (Please circle number of your answer.)
    1. YES
    2. NO

13. What proportion of neighboring farms do you believe use atrazine on their corn fields? (Please circle number of your answer.)
    1. LESS THAN 1/4
    2. 1/4 TO ½
    3. ½ TO 3/4
    4. 3/4 TO ALL

The next set of questions uses atrazine as an example only because most farmers are familiar with it. The purpose is NOT to evaluate atrazine.

14. The following table summarizes published findings about the major health and environmental effects of atrazine. Have you heard about any of these? (Please check each item you have heard about.)

HEALTH AND ENVIRONMENTAL EFFECTS	I HAVE HEARD ABOUT THIS (✓)
POSSIBLE HUMAN CARCINOGEN	A
SLIGHTLY TO MODERATELY TOXIC TO MAMMALS	B
NOT A REPRODUCTIVE TOXIN	C
MAY CAUSE IRRITATION OF THE MUCUS MEMBRANE	D
MILD SKIN IRRITANT	E
SEVERE EYE IRRITANT	F
SLIGHTLY TOXIC TO BIRDS	G
SLIGHTLY TOXIC TO FISH	H
NON-TOXIC TO BEES	I
HIGH PROBABILITY OF LEACHING IN MOST SOILS	J
LENGTHY SOIL HALF LIFE (60 TO 100+ DAYS)	K

15. Now we want to ask **YOUR** opinion about the published health and environmental effects of atrazine. Do you agree that atrazine has these effects? (Please indicate your opinion by checking [✓] **one** box beside each item below.)

HEALTH AND ENVIRONMENTAL EFFECTS	AGREE	DISAGREE		UNSURE
		THE EFFECT IS MORE	THE EFFECT IS LESS	
POSSIBLE HUMAN CARCINOGEN				
SLIGHTLY TO MODERATELY TOXIC TO MAMMALS				
NOT A REPRODUCTIVE TOXIN				
MAY CAUSE IRRITATION OF THE MUCUS MEMBRANE				
MILD SKIN IRRITANT				
SEVERE EYE IRRITANT				
SLIGHTLY TOXIC TO BIRDS				
SLIGHTLY TOXIC TO FISH				
NON-TOXIC TO BEES				
HIGH PROBABILITY OF LEACHING IN MOST SOILS				
LENGTHY SOIL HALF LIFE (60 TO 100+ DAYS)				

16. Which of the following sources of information on the health and environmental effects of herbicides do you use on a regular basis?
(Please circle numbers of **all** that apply.)

1. HERBICIDE DEALER
2. CHEMICAL LABEL
3. CHEMICAL COMPANY SALESMAN
4. TRADE MAGAZINE
5. MSU EXTENSION
6. ANOTHER FARMER
7. CONSULTANT/AGRONOMIST
8. MATERIAL SAFETY DATA SHEETS
9. NEWSPAPERS
10. CUSTOM APPLICATOR
11. MY OWN EXPERIENCE
12. OTHER (Please list) ___________

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.

17. 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 $3.00 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

If you answered NO to Question 17, please go to Question 20.

18. Now suppose you have used the new formulation of atrazine on the acres you listed in Question 17 for three years. If the new formulation worked as well as regular atrazine for all three years, on how many acres would you use the new formulation if it was still available for $3.00 per pound and other conditions are like this spring? (Please write in number of acres.)

_______ SOIL APPLIED _______ FOLIAR APPLIED

19. What is the **most important benefit** to you from using the formulation of atrazine that does not leach? (Please choose only **one** answer and circle it.)

1. LESS HEALTH RISK TO MY HOUSEHOLD
2. LESS HEALTH RISK TO OTHER PEOPLE
3. LESS RISK OF FUTURE GOVERNMENT REGULATION
4. LESS RISK TO ANIMALS
5. OTHER (Please describe) _________________________

20. Suppose a chemical company made a new formulation of atrazine that was identical to regular atrazine in every way (including leaching), except the new formulation **does not cause cancer in humans**. This new formulation is available for $3.00 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

If you answered NO to Question 20, please go to Question 23.

21. Now suppose you have used the new formulation of atrazine on the acres you listed in Question 19 for three years. If you found the new formulation worked as well as regular atrazine for all three years, on how many acres would you use the new formulation if it was still $3.00 per pound and other conditions are like this spring? (Please write in number of acres.)

_______ SOIL APPLIED _______ FOLIAR APPLIED

22. What is the **most important benefit** to you from using the formulation of atrazine that does not cause cancer. (Please choose only **one** answer and circle it.)

    1. LESS HEALTH RISK TO MY HOUSEHOLD
    2. LESS HEALTH RISK TO OTHER PEOPLE
    3. LESS RISK OF FUTURE GOVERNMENT REGULATION
    5. OTHER (Please describe) ________________

23. Suppose a chemical company made a new formulation of atrazine that was identical to regular atrazine in every way (including leaching and cancer risk), except the new formulation is **non-toxic to fish**. This new formulation is available for $3.00 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

If you answered NO to Question 23, please skip Question 24.

24. Suppose you have used the new formulation on the acres you listed in Question 23 for three years. If the new formulation worked as well as regular atrazine for all three years, on how many acres would you use the new formulation if it was still $3.00 per pound and other conditions are like this spring? (Please write in number of acres.)

    ______ SOIL APPLIED ______ FOLIAR APPLIED

Now we would like to ask you some questions about your farm.

25. Is there any body of water containing fish within 1/4 mile of your corn fields? (Please circle number of your answer.)

    1. YES
    2. NO

26. What is your primary source of drinking water?
(Please circle number of your answer.)

1. BOTTLED WATER
2. UNTREATED WATER FROM A PRIVATE WELL
3. TREATED WATER FROM A PRIVATE WELL
4. MUNICIPAL WATER

If you did not answer BOTTLED WATER, please go to Question 28.

27. What is your primary reason for purchasing bottled water?
(Please circle number of your answer.)

1. WATER FROM A PRIVATE WELL IS CONTAMINATED FROM PESTICIDES
2. WATER FROM A PRIVATE WELL IS CONTAMINATED FROM OTHER SOURCES
3. WATER FROM PRIVATE WELL TASTES BAD
4. MUNICIPAL WATER TASTES BAD
5. OTHER (Please describe) ________________

28. How deep is the water well for your house? (Please write in depth.)

1. DEPTH IS _______ FEET
2. WE DO NOT HAVE A WATER WELL FOR OUR HOUSE

If you DO NOT HAVE A WATER WELL FOR YOUR HOUSE, please go to Question 32.

29. Has your household water well been tested for the presence of agricultural chemicals?
(Please circle number of your answer.)

1. YES
2. NO

If you answered NO to the previous question, please go to Question 31.

30. When was this test conducted and what were the results of this test?
(Please write in year and describe results.)

____

____

31. How close to your household water well is your nearest corn field? (Please circle number of your answer.)

1. LESS THAN 100 FEET
2. BETWEEN 100 FEET AND 500 FEET
3. GREATER THAN 500 FEET

These last few questions are needed to compare your opinions with other Michigan farms we are surveying. Your answers will be kept completely confidential.

32. What is your gender? (Please circle number of your answer.)
    1. MALE
    2. FEMALE

33. What is your age? (Please write in age.) _______ YEARS

34. How many years since the age of 18 have you been operating a farm?(Please write in number of years.) _______ YEARS

35. Other than yourself, how many members of your household are in each of the age groups below?(Please write in number.)

AGE 2 AND UNDER	____	AGES 18 TO 40	____
AGES 3 TO 5	____	AGES 41 TO 64	____
AGES 5 TO 17	____	AGE 65 AND OVER	____

36. This year during May and June, approximately how many hours per week did you spend working off the farm? (Please write in number of hours.) _______ HOURS/WEEK

37. Which is the highest level of education that you have completed? (Please circle number of your answer.)

1. LESS THAN 12 YEARS
2. COMPLETED HIGH SCHOOL
3. TECHNICAL TRAINING BEYOND HIGH SCHOOL
4. SOME COLLEGE
5. COMPLETED COLLEGE
6. SOME GRADUATE WORK
7. GRADUATE DEGREE

38. Which of the following best describes your household's adjusted gross income (line 31 of Federal tax return) for 1994? (Please circle number of your answer.)

1. LESS THAN $9,999
2. BETWEEN $10,000 AND $24,999
3. BETWEEN $25,000 AND $49,999
4. BETWEEN $50,000 AND $74,999
5. GREATER THAN $75,000

39. Roughly what percent of your household's adjusted gross income in a typical year can be attributed to farming? (Please write in percent.) ________ %

40. Roughly what percent of your household's adjusted gross income typical year can be attributed to livestock or poultry? (Please write in percent.) ________ %

THANK YOU VERY MUCH FOR COMPLETING THIS SURVEY. WE GREATLY APPRECIATE YOUR HELP.

If you would like to share any additional comments, please write on this page.

If you would like a copy of the results of this study, please print your name and address on the back of the return envelope. Please do not put this information on this questionnaire.

APPENDIX B

Appendix B

Herbicide Choice Telephone Survey Script

October 4, 1995

Hello, is this (telephone number)?

My name is and I represent the Michigan State University.

We are conducting a brief study of Michigan corn producers who were recently sent a questionnaire on corn herbicide use by the Department of Agricultural Economics at Michigan State University. I only have a few short questions. Of course answering them is completely voluntary and the answers will be confidential.

(Q1a) May I speak to (insert name)?

NO	---------Thank you very much for your time. Good bye. *If dead, sold farm, moved, not farming, etc. write in Q12*
NOT HOME, ETC.	---------May I speak to spouse.
YES, ME	---------GO TO Q2
YES, OTHER	

After that person is on this line....

My name is and I represent the Michigan State University.

We are conducting a brief study of Michigan corn producers who were recently sent a questionnaire on corn herbicide use by the Department of Agricultural Economics at Michigan State University. I only have a few short questions. Of course answering them is completely voluntary and the answers will be confidential.

(Q1b) May I ask you a few questions on this subject?

NO ---------Thank you very much for your time. Good bye.
YES

(Q2) Did you recently receive a questionnaire about corn herbicide use from the Department of Agricultural Economics at Michigan State University?

NO ---------GO TO Q4 *SKIP Q12*
REFUSED ---------GO TO Q4 *SKIP Q12*
DON'T KNOW -------- GO TO Q4 *SKIP Q12*
YES

(Q3) Did you complete and return the questionnaire?

YES ---------Thank you very much for your time and for returning the survey. We appreciate your help very much. Good bye.
REFUSED
DON'T KNOW
NO

(Q4) Is this a farm?

NO --------Thank you very much for your time. This is all the information we need. Good bye.
DON'T KNOW--------Thank you very much for your time. This is all the information we need. Good bye.
REFUSED
YES

(Q5) Did you plant corn this year?

NO -------Thank you very much for your time. This is all the information we need. Good bye.
DON'T KNOW --------Thank you very much for your time. This is all the information we need. Good bye.
REFUSED
YES

(Q6) How many acres of tillable land are you farming this year, including set aside?

REFUSED
DON'T KNOW
ACRES

(Q7) How many of the acres that you farm were planted with corn this year?

REFUSED
DON'T KNOW
ACRES

(Q8) Did you use herbicides on any of the corn you planted?

NO --------Thank you very much for your time. This is all the information we need. Good bye.
REFUSED
DON'T KNOW
YES

(Q9) Roughly what percent of your household's adjusted gross income in a typical year can be attributed to farming?

DON'T KNOW --------*Roughly* what percent?
REFUSED
PERCENT

(Q10) Roughly what percent of your household's adjusted gross income in a typical year can be attributed to livestock or poultry?

DON'T KNOW --------*Roughly* what percent?
REFUSED
PERCENT

(Q11) Which is the highest level of education that you have completed?

LESS THAN 12 YEARS
COMPLETED HIGH SCHOOL
TECHNICAL TRAINING BEYOND HIGH SCHOOL
SOME COLLEGE
COMPLETED COLLEGE
SOME GRADUATE WORK
GRADUATE DEGREE
DON'T KNOW
REFUSED

(Q12) Do recall why you did not choose to return the questionnaire?

Thank you very much for your time. Good bye.

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