Staff Paper

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Abstract:

Will Farmers Use Safer Pesticides?

Virtually all technology adoption studies are conducted ex post, yet policy makers often need to assess the likely level of adoption before the technology is introduced. This study uses data from a contingent valuation survey of Michigan corn growers to assess what factors would influence the adoption of two safer corn herbicides, one that is not carcinogenic and one that does not leach. Results indicate that price, risk perception, and sources of pest control information are all important. This suggests that public policies designed to change perceptions and improve information dissemination may encourage voluntary use of more environmentally friendly technologies.

Key words: atrazine, cancer risk, contingent valuation, herbicides, nitrate leaching, public policy, technology adoption

Will Farmers Use Safer Pesticides?

Introduction

Herbicides are an important input in the production of many agricultural commodities. However, it is well documented that these chemicals can have a variety of adverse effects on both human health and the environment including contamination of groundwater and surface water, chronic and acute health effects in humans, fishery losses, and adverse effects of other forms of wildlife. While it has been shown that farmers are concerned about human health and the environment (Higley and Wintersteen; Beach and Carlson), little is known about whether and which farmers would use more environmentally friendly herbicides should they be developed.

For obvious reasons, most studies of technology adoption have been conducted after the technology has been introduced. While this knowledge is useful, it may also be instructive to have estimates of the percentage of farmers willing to adopt and factors influencing the decision to adopt *prior* to the introduction of the technology.

This paper presents results of an empirical study examining the potential for adoption 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, being used on over 65 percent of U.S. corn acreage (Ribaudo and Bouzaher). Moreover, a variety of adverse health and environmental effects have been associated with atrazine including contamination of groundwater and cancer in humans (Blair and White; Hoar et al.; Wigle et al.; Ribaudo and Bouzaher). In a survey of Michigan corn farmers, Owens, Swinton and van Ravenswaay (In Press) offered respondents the option of purchasing either atrazine or a hypothetical “new” formulation of atrazine, one described as non-leaching and the other as non-carcinogenic. Thus, two specific safer herbicides are examined. The remainder of the paper begins with a discussion of factors affecting adoption of environmentally friendly agricultural technologies as gathered from previous literature. Presented next is the empirical approach taken. A discussion of the data and econometric method utilized follow. Finally, results are presented and discussed.

Prior Research

Studies investigating significant characteristics associated with adopters (or non-adopters) of agricultural technologies/practices (both environmentally friendly and general agricultural technologies) have identified numerous such characteristics. Although the exact classifications of characteristics differ by author, these characteristics can generally be grouped into four categories; farm characteristics, household characteristics, technology characteristics, and institutional factors (Feder, Just, and Zilberman).

Commonly explored farm characteristics include farm size, land tenure, and various biophysical traits (Nowak; Rahm and Huffman). Although some form of these variables were included in virtually all studies addressing adoption of environmentally friendly technologies, the signs and significance level of farm characteristic variables varied depending on the specific technology examined. As an illustration, McNamara Wetzstein, and Douce found acreage to be insignificant in explaining peanut producers’ decision to use integrated pest management while Rahm and Huffman found acreage positively impacted the probability that Iowa farmers adopt reduced tillage.

Personal characteristics examined in these types of adoption studies include age and education (Taylor and Miller; Ervin and Ervin; Rahm and Huffman; Nowak; D'Souza, Cyphers, and Phipps). Generally, education has been shown to enhance the likelihood of adopting environmental technologies (Taylor and Miller; Ervin and Ervin; McNamara, Wetzstein, and Douce). Age has also been shown to be influential; however the sign of the impact has varied. For example, D'Souza, Cyphers, and Phipps found younger farmers were more likely to adopt a package of sustainable agricultural techniques, while McNamara, Wetzstein, and Douce found older farmers were more prone to adopt integrated pest management.

Institutional variables include such things as awareness of environmental problems, credit constraints, availability of information, availability of extension assistance, and use of extension services (Rahm and Huffman; Nowak; Harper et al.; McNamara, Wetzstein, and Douce). Generally the institutional variables listed above, with the exception of credit constraints, have positively affected adoption of environmental technologies. Harper et al. found that attendance at various Texas Agricultural Experiment Station field days positively affected the decision of rice farmers to use sweep nets. McNamara, Wetzstein, and Douce found farmers who received integrated pest management literature from extension agents were more likely to adopt that approach to pest management.

In addition to the above factors found to influence adoption, studies dealing specifically with adoption of environmental innovations, technologies designed specifically for the purpose of preserving existing resources, found farm orientation is important. In an early study dealing specifically with adoption of practices designed to protect the environment, Pampel and van Es 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.

Pampel and van Es found that farm orientation is important in prediction of adoption of environmental innovations. In addition, many later studies provided further evidence that farming orientation is an important factor explaining adoption of environmentally friendly technologies. Taylor and Miller found that Amish, who are committed to farming as a way of life, near the Maumee River in northern Indiana were more likely to adopt farm practices designed to reduce soil erosion than non-Amish farmers. McNamara, Wetzstein, and Douce found percent of total income from farming activities was positively and significantly related to peanut producers’ decision to adopt integrated pest management. Integrated pest management is an approach to crop protection that advocates chemical control only when economically justified rather than at prescribed times. The approach often leads to reduced chemical use. D’Souza, Cyphers, and Phipps found off-farm employment was negatively and significantly related to the decision to adopt a package of sustainable agricultural techniques.

The discussion of factors affecting adoption of environmental technologies presented above relies heavily on studies involving soil conservation techniques and integrated pest management. No adoption study was found dealing with agricultural chemicals in general or a specific agricultural chemical. However, research suggests that farmers are concerned about the impact of these chemicals on both human health and the environment and provides some evidence that farmers would be interested in using these chemicals. Higley and Wintersteen surveyed field crop producers in order to estimate willingness to pay for reductions in the environmental impacts of pesticide application. Their results indicate that producers were willing to pay upwards of $12 to avoid a high level of risk associated with a single application of an agricultural pesticide. Beach and Carlson used hedonic analysis of herbicide prices to determine which characteristics are important determinants of herbicide selection. In some of their models, water quality and user safety were found to be important determinants of herbicide choice.

Empirical Approach

Adoption of a new production technology will generally take place when the technology increases expected profit. However, it is widely accepted that factors other than profit may also motivate farmers. It has been shown that a utility-maximizing farmer who values health, leisure, consumption and environmental quality will exhibit marginal willingness to pay for a new herbicide that is safer in terms of its effect on human health and/or the environment that is positive or at least non-negative (Cropper and Freeman; Owens, Swinton and van Ravenswaay, 1995). Whether or not the safer herbicide is actually purchased depends on its perceived effect health and environmental quality, the price of the new herbicide, and the nature of the farmer's utility function. Thus, concern for health and the environment may motivate farmers to use safer herbicides.

In analyzing factors that affect herbicide adoption, it is assumed that farmers maximize a utility function whose arguments include health (h), environmental quality (v), and net returns (r). For further elaboration, see Owens, Swinton and van Ravenswaay (1995).

Assume that there are currently two herbicides available: the subscript 0 indexes the herbicide currently being used and the subscript s indexes the new, safer herbicide. Although the new herbicide may cost more and therefore decrease net returns, use of the new herbicide increases both health and environmental quality. The utility from adopting the new herbicide is the difference between the utility derived from use of the old herbicide and the utility derived from use of the new herbicide,

$$U(adopting) = U(h_s, v_s, r_s) - U(h_0, v_0, r_0). \tag{1}$$

The utility from adopting may be either positive or negative. Following Rahm and Huffman, a linear relationship is assumed between the utility derived from herbicide adoption and a vector of observable farm and operator characteristics,

$$U(adopting) = X\beta + \epsilon. \tag{2}$$

In this application of a random utility model, the observable characteristics come from the four categories discussed previously: farm characteristics, household characteristics, technology characteristics, and institutional factors. Although, utility cannot be observed, what can be observed is whether or not the new herbicide is used (Maddala). Let A index the adoption decision. Thus, A=1 is observed if the new herbicide is adopted and A=0 is observed if the new herbicide is not adopted:

(3)
$$A=1 \ \text{if} \ U(adopting) - \epsilon \geq X\beta$$
$$A=0 \ \text{if} \ U(adopting) - \epsilon < X\beta.$$

The data used in this study were taken from a survey of 2000 Michigan corn farmers conducted by Owens, Swinton, and van Ravenswaay (In Press). The sample of responses analyzed consisted of 669 useable records from corn farms that used herbicides. Respondents were asked to consider whether they would use, in 1996, regular atrazine or a hypothetical alternative formulation of atrazine. One alternative formulation was described as not leaching into groundwater. A second formulation was described as not causing cancer in humans. 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. Respondents also answered questions about farm and personal characteristics, as well as their awareness and attitudes toward scientific assessments of the health and environmental risks associated with atrazine use.

A farmer is considered to be willing to adopt the new herbicide (A=1) if he indicated willingness to use it on some corn acreage in the next year (1996). Assuming the disturbance term ϵ above follows a normal probability distribution, probit models were applied to explain the adoption of hypothetical atrazine formulations described as either non-leaching or non-carcinogenic. The explanatory variables came from the general categories: farm orientation, farm characteristics, personal characteristics, and price (Table 1).

Since farmers who view farming as a way of life have been more likely to adopt environmental innovations it was expected that HOURS WORK would be negatively related to the probability of adoption of both the non-leaching and non-carcinogenic formulations. A common proxy for farm orientation is hours worked off farm.

Farm characteristics included in the model are ACRES CORN and ATRAZINE95. Acreage was included, but with no prior expectation regarding the direction of its effect. ATRAZINE95 was expected to have a positive coefficient 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 have also been shown to be important, although study-specific. Such characteristics included in this model are RESIST, IRRIGATE, WEED PRESSURE, USE NEAR, and CONTAMINATED WATER. Farmers with weeds resistant to atrazine should be less likely to purchase the new herbicides as they were described as being identical to regular atrazine except in terms of leaching or human cancer. Any weeds resistant to regular atrazine will also be resistant to the new formulations. As the amount of irrigation carried out on farm increases, the risk of herbicide, or any other chemical, leaching increases. Thus, it is expected that IRRIGATION will positively effect the probability of adoption of the non-leaching formulation. WEED PRESSURE was felt to be relevant, but the researchers had no prior expectation of its sign, 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 is uncertain. A farmer may be more likely to adopt if he seeks to compensate for atrazine use on neighboring farms or he less likely to adopt if he feels helpless. Similarly, if a farmer's well has been shown to be contaminated, arguments in favor of negative and positive impacts on adoption can be made.

The risk of chemicals leaching is greater in sandy soils, therefore it was expected that soil texture would also affect the decision to purchase the non-leaching herbicide. However, it was found to be insignificant and removed from the final equation.

Personal characteristics included in the model are EXPERIENCE, INCOME, and CHILDREN. Experience in farming also leads to experience in handling, applying, and storing chemicals. Thus, it was hypothesized that experience will have a negative effect on the probability of adoption. The demand for a normal good increases with income, therefore, the effect of percent of household income derived from farming on the probability of adoption is expected to be positive. Children are more susceptible to health problems due to exposure to chemicals. Thus, it is expected that the presence of children will positively effect the probability of adoption.

Adoption of the alternative formulations should increase with an increase in farmers' perceptions of atrazine's potential to leach into and remain in groundwater utilized by the farm, potentially causing human health problems. Half life and leaching go hand in hand in determining potential exposure. Thus, two additional variables related to risk perceptions were included, LEACH and HALF LIFE. The belief that atrazine is less likely to leach than is scientifically held was expected to reduce the probability of adopting the new compounds as is the belief that the half life of atrazine is shorter that is scientifically believed.

Different sources present information on the health and environmental effects of chemicals differently. Therefore, it was expected that reliance on certain information sources (DEALER, LABEL, MAGAZINE, MSU, NEWSPAPER) would influence the decision to purchase the new herbicides, but no prior assumptions were made regarding the direction of influence.

Finally, the price difference between the new formulations of atrazine and conventional atrazine was included. Price is negatively related to the demand for a normal good. Hence it was hypothesized that as the price of the new formulations became more expensive relative to regular atrazine, the probability of adoption would decrease.

Results

Descriptive statistics for the variables included in the two models are presented in Table 2. The estimated level of prospective adoption for the non-leaching formulation and no-cancer formulations are 50 percent and 48 percent, respectively. The mean level of prospective adoption for all farmers answering the purchase intention questions was 43 percent for the non-leaching formulation and 46 percent for the no-cancer formulation. The final sample consisted of 293 and 363 records for the non-leaching and no-cancer formulations, respectively.[1]

Probit regression results for the adoption of the new formulations of atrazine are presented in Table 3. The likelihood ratio index (LRI) is presented as a measure of goodness of fit (Pindyck and Rubinfeld; Greene). The likelihood ratio index is given by the following:

$$LRI = 1 - \frac{L(\beta)}{L(0)}.$$

[1]In all, 303 and 379 records were actually complete for all variables ultimately included in the equations for the non-leaching and no-cancer formulations. However, since several observations lacked explanatory variables affecting the level of herbicide consumption, those observations were omitted from this analysis.

where L(0) is the value of the log likelihood function when all parameters are zero, except the intercept, and L(β) is the maximum value of the log likelihood function. Like R^2, values of LRI range from 0 to 1. The LRI for the equation modeling adoption of the non-leaching formulation is 0.20. The LRI for the equation modeling adoption for the no-cancer formulation is 0.15. LRIs ranging from .15 to .45 have been common in recent studies examining the adoption of integrated pest management (Harper et al.; Swinton, Cuyno, and Lupi).

An alternative measure of goodness of fit is the prediction rate. The prediction rate compares a model's predictions of the adoption decision with the actual choice made by the respondent. Results indicate the model correctly predicts the decision to adopt the non-leaching formulation 73.9 percent of the time and the decision not to adopt 68.7 percent of the time. Similarly, the model correctly predicts the decision to adopt the no-cancer formulation 68.6 percent of the time and the decision not to adopt 69.7 percent of the time.

Results from the probit regression indicate that the probability of purchasing the formulation of atrazine that does not leach is significantly enhanced by the belief that most neighbors use atrazine (USE NEAR), the presence of weeds resistant to atrazine (RESIST), agreement with scientific evidence regarding the leaching risk and half life of atrazine (LEACH and HALF LIFE), and prior use of atrazine (ATRAZINE95). Factors that reduce the probability of purchasing the non-leaching formulation included corn acreage (ACRESCORN) and PRICE DIFFERENCE. All signs are consistent with prior expectations, except for the sign on RESIST.

The positive USE NEAR 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. 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 some evidence that risk perceptions, as measured by respondents' opinions as to the leaching effect and half life of atrazine related to those of the scientific community, also affects the probability of adoption.

Contrary to expectations, HOURS WORKED, the proxy for farm orientation, does not have a significant effect on the probability of adoption of the non-leaching herbicide. This may be explained by the possible human health effects associated with herbicide use. That is, adoption of this environmental innovation will not only protect farming resources (such as groundwater) but may also benefit human health (less possible exposure via groundwater). If both "way of life" farmers and business oriented farmers are equally concerned about the health of themselves and their families, the adoption decision may not be affected by farm orientation.

Results from the probit regression of the no-cancer formulation indicate that the probability of adoption of this formulation is enhanced by USENEAr and NEWSPAPER. The probability of adoption of the no-cancer formulation is reduced by PRICE DIFFERENCE and MAGAZINE.

Again, the estimated coefficient on USE NEAR is positive, providing further evidence that farmers may try to compensate for the chemical use decisions of their neighbors. As expected, the difference in price between the new and conventional formulations of atrazine reduces the probability of adopting the new formulation. The farm orientation proxy, HOURS WORK, does not appear in the regression for the no-cancer formulation, further suggesting 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 from Michigan State University Extension and newspapers favored the adoption of the non-carcinogenic formulation.

Conclusions

These results provide further evidence that farmers are concerned about both human health and the environment in general and care specifically about herbicide leaching and cancer. They also highlight the potential for voluntary adoption of more environmentally friendly pest control methods. Approximately 50 percent of farmers indicated that they would use some of the formulation of atrazine that does not leach, while 48 percent indicated they would use some of the no-cancer formulation. Those farmers indicating they would use the new formulations are likely to be early adopters. The results presented here provide no insight as to how the adoption rates would change over time should these herbicide actually be introduced.

Researchers continue to try to 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 rates of environmentally friendly chemicals. For example, it is known that large farms are less likely to purchase the atrazine alternatives discussed here. There is no reason to believe that this result will be different for an agricultural chemical that is less toxic to bees, fish, humans, etc. Thus, when one such chemical is introduced, early information campaigns should target smaller farms, those most likely to adopt.

Perceptions of scientific knowledge about leaching potential appear to be important to adoption of environmental innovations. Scientific evidence suggests that atrazine has a high probability of leaching and a lengthy soil half life. Respondents who agreed with or felt the scientific evidence understates the leaching problem were more likely to decide to purchase the new formulations. Those who agreed with scientific opinion on the half life of atrazine were more likely to purchase the non-leaching formulation. This suggests that educational policies--perhaps including more comprehensible herbicide safety labeling--may be more effective at encouraging voluntary use of more environmentally friendly technologies than currently used tax approaches to chemical regulation.

The results also offer insights about encouraging demand for safer herbicides among prospective adopters. Sources of information were especially influential in the decision to purchase the non-carcinogenic formulation. While further research is needed to more completely describe the relationship between information sources and technology adoption, these results suggest that public educational policies would be enhanced by targeting independent information sources, such as university extension services and newspapers, and heavily used sources such as herbicide labels.

Table 1. Variables Included in Adoption Equations

Variable	Meaning
FARM ORIENTATION	
HOURS WORK	hours worked off farm
FARM CHARACTERISTICS	
ACRES CORN	acres of corn farmed
ATRAZINE95	(0,1)used some form of atrazine in 1995
RESIST	(0,1) weeds resistant to atrazine
IRRIGATE	% of corn fields that are irrigated
WEED PRESSURE	(0,1) more than slight weed pressure
USE NEAR	(0,1) more than ½ of neighboring farms use atrazine
CONTAMINATED WATER	(0,1) well water contaminated from agricultural chemicals
PERSONAL CHARACTERISTICS	
EXPERIENCE	farming experience
INCOME	household adjusted gross income
CHILDREN	(0,1) have children under age 18
LEACH	(0.1) believes atrazine leaching effect is overstated by scientific community
HALF LIFE	(0.1) believes atrazine half life is overstated by scientific community
DEALER	(0,1) uses chemical dealer as source of information
LABEL	(0,1) uses chemical label as source of information
MAGAZINE	(0,1) uses trade magazine as source of information
MSU	(0,1) uses MSU extension as source of information
NEWSPAPER	(0,1) uses newspaper as source of information
OTHER	
PRICE DIFFERENCE	price difference between new and conventional atrazine formulations

Table 2. Descriptive Statistics

Variable	Non-leaching Formulation (N=293) Mean	Non-leaching Formulation (N=293) Standard Deviation	No Cancer Formulation (N=363) Mean	No Cancer Formulation (N=363) Standard Deviation
ADOPT NON LEACH	0.50	0.50		
ADOPT NO CANCER			0.48	0.50
HOURS WORKED	15.60	21.70		
ACRES CORN	179.00	229.00	184.00	274.00
ATRAZINE95	0.80	0.40	0.77	0.42
RESIST	0.49	0.50	0.48	0.50
IRRIGATE	4.05	16.11	3.50	15.07
WEED PRESSURE	0.76	0.43		
USE NEAR	0.68	0.47	0.65	0.48
CONTAMINATED WATER	0.02	0.14		
EXPERIENCE	26.40	11.50	26.90	11.60
INCOME	43,500.00	27,100.00	42,600.00	26,000.00
CHILDREN	0.48	0.50		
LEACH	0.41	0.49	0.43	0.50
HALF LIFE	0.44	0.50		
DEALER	0.66	0.48		
LABEL			0.80	0.40
MAGAZINE			0.40	0.49
MSU			0.49	0.50
NEWSPAPER			0.12	0.33
PRICE DIFFERENCE	1.87	1.80	1.95	1.85

Table 3. Probit Regression Results

Variable	Non-leaching Formulation Estimate (Standard Error)	No Cancer Formulation Estimate (Standard Error)
CONSTANT	0.39E-1 (0.50)	-0.60E-1 (0.33)
HOURS WORKED	-0.16E-2 (0.41E-2)	
ACRES CORN	*** -0.13E-2 (0.49E-3)	-0.40E-3 (0.27E-3)
ATRAZINE95	* 0.40 (0.23)	0.26 (0.19)
RESIST	** 0.38 (0.17)	-0.46E-1 (0.15)
IRRIGATE	-0.26E-2 (0.53E-2)	-0.71E-2 (0.49E-2)
WEED PRESSURE	-0.16 (0.20)	
USE NEAR	*** 0.49 (0.19)	*** 0.74 (0.17)
CONTAMINATED WATER	-0.68 (0.62)	
EXPERIENCE	-0.13E-1 (0.87E-2)	-0.70E-2 (0.62E-2)
INCOME	0.49E-5 (0.32E-5)	0.22E-5 (0.28E-5)
CHILDREN	0.47E-1 (0.20)	
LEACH	* 0.31 (0.17)	0.15 (0.14)
HALF LIFE	** 0.41 (0.17)	
DEALER	-0.21 (0.17)	
LABEL		-0.16 (0.18)
MAGAZINE		* -0.30 (0.16)
MSU		0.23 (0.15)
NEWSPAPER		* 0.42 (0.22)
PRICE DIFFERENCE	*** -0.27 (0.48E-1)	*** -0.23 (0.41E-1)
Summary Statistics	LRI=.20	LRI=.15
	Adoption Prediction Rate=.739	Adoption Prediction Rate=.686
	Non-adoption Prediction Rate=.687	Non-adoption Prediction Rate=.697

***= significant at 1%, **=significant at 5%, *=significant at 10%

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