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FS 96-10 May, 1996

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ABSTRACT---
Farmers' willingness to voluntarily reduce insecticide use is not considered when regulatory approaches to environmental protection are proposed. Regulations that require behavior that would voluntarily be undertaken are excessive and economically inefficient. Using survey data from a contingent valuation scenario, we demonstrate the willingness of crop producers in four Midwestern states in the U.S. to trade yield losses for environmental risk reduction by eliminating an insecticide application. The mean acceptable yield loss for a sample of 1,138 producers in Illinois, Iowa, Nebraska and Ohio is $8.25 per acre. Acceptable yield loss increases with the rated importance of environmental goods (fish, birds, mammals, native plants and endangered species), with formal education and with farming experience. Willingness to pay increase with total expenditure on herbicides and insecticides up to $89 per acre, then decreases as total expenditure continues to rise. We approximate that crop farmers in the four states are willing to give up over $420 million in yield losses, or about 4 percent of total sales of corn and soybeans, to guarantee protection of eleven environmental goods from moderate insecticide risk. Uncertainty about risks, dominance of regulatory approaches and economic pressures undercut voluntary reductions in insecticide use.

-----KEY WORDS-----
Decision models, agriculture, environmental protection, risk, contingent valuation

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1. Introduction

Increasing public concern for the environmental effects of insecticides has escalated pressure on farmers to reduce insecticide use. Awareness of risks to the environment and human health, particularly ground water quality, and improved detection methods have stimulated state regulations in the U.S. (Wise and Johnson, 1991; Blomquist, 1991). Hall and Kerr (1992) quantified state policy initiatives and state leadership in environmental regulations, including those that affect agriculture. Farmers' willingness to voluntarily reduce insecticide use is not considered when regulations are implemented.

Insecticide reduction has two risk consequences for farmers, potential gains in environmental quality and possible yield loss, resulting in monetary loss to the operation. Chemical use restrictions and management recommendations incorporate the regulator's evaluation of these risk tradeoffs, not necessarily the farmer's. For example, potential crop loss may be calculated as the economic injury level, which mathematically relates management costs to expected value of crop loss (Pedigo and Higley, 1992). Environmental gains may be calculated from chemical properties, use levels and susceptibility of affected environmental components (Teague et al., 1995; Higley and Wintersteen, 1992). Such concepts are useful in quantifying technical and economic impacts of regulations, but fail to account for farmers' valuations of acceptable tradeoffs, which may be the basis for equally effective voluntary insecticide reductions. As a result, regulatory controls may be excessive in scope and severity.

Insecticide use decisions implicitly trade off these risks, balancing expected environmental gains with expected yield loss. The true risk levels and their relationships to insecticide use are not known with certainty by the farmer. However, each farmer forms subjective estimates of the

probabilities and values of decision outcomes and these expectations are known with certainty to him or her. These subjective estimates may be elicited to quantify the effect of risk perceptions on voluntary insecticide use decisions.

Previous research in support of regulatory approaches has ignored farmers' willingness to adopt voluntary insecticide reductions. In this study, we demonstrate the willingness of farmers to trade yield losses for environmental gains, and we identify the determining factors in this choice. We assess the value of voluntary insecticide reductions by crop farmers in four Midwest states in the U.S., indicating the potential for improvements in environmental protection without additional regulation.

2. Method

2.1. VALUING RISK TRADEOFFS

The tradeoff between environmental benefits and yield loss is valued through the farmer's underlying utility function, which he or she maximizes in decision making. The attitudes a farmer expresses reveal this underlying utility function and the expectations about risks of costs and benefits from reducing insecticide applications.

Cost to the farmer is acceptable yield loss, measured as expected revenue loss. This value is the upper limit on willingness to pay for gains from insecticide reduction, since any lesser yield loss down to zero would also be acceptable if the same benefits were gained. Benefit to the farmer is protection of the environment, measured as the subjective rating of importance in protecting amenities from insecticide impacts.

Expected monetary losses depend on systems effects beyond the cost of chemicals and their application, since management and labor adjustments are also required (Carlson, 1988). The

expected cost of alternative activities and revenue loss due to yield effects of chemical reduction is quantifiable as the acceptable value of yield loss to each farmer.

Individuals may have difficulty assessing values for environmental goods that are not directly consumed as commodities or production inputs, due to lack of experience with the goods and disassociation of actions with environmental consequences (Diamond and Hausman, 1993). Unrealistic attitudes about the affordability and method of payment for the perceived benefits of an environmental good also hinder valuation efforts (Mitchell and Carson, 1989). An individual who recognizes the importance of an environmental good may offer a payment for the good that exceeds his or her budget constraint.

Evidence from surveys in Nebraska suggests that farmers are better prepared than the general public to evaluate the risk tradeoff as they have more information about both benefits and costs of reducing pesticide use (Rockwell et al., 1991b). Farmers have a clear sense of their budget constraints, and have experiential and science-based information on the yield risk from cutting back insecticide use (Rockwell et al., 1991b). Also, farmers have demonstrated greater awareness of environmental impacts of management decisions, particularly for ground and surface water (Rockwell et al. 1991a, 1991b). From these characteristics, we used utility theory to model farmers' willingness to trade off yield loss for environmental protection.

2.2. THE DECISION FRAMEWORK

Following Smith and Desvousges (1990), we developed an indirect utility function describing the producer's choices of insecticide application rates conditional on environmental risks. Let V_p be the utility of wealth when the producer maintains current insecticide use, but gains no environmental benefits. Let V_{np} be the utility of wealth when the producer chooses a voluntary reduction in insecticide applications associated with positive environmental impacts.

The indirect utility function depends on the producer's income level (Y), vectors of the individual's environmental attitudes, demographic and farm characteristics (Z) and regulatory and environmental conditions in the grower's state (S). Acceptable yield loss (L) is the dollar amount that equates the conditional *ex ante* indirect utility functions for the two choices so that

$$V_p(Y, Z, S) + \epsilon_p = V_{np}(Y - L, Z, S) + \epsilon_{np} \tag{1}$$

Random elements that influence the indirect utility function are given by ϵ, with appropriate subscripts for the two choices. Equation 1 shows that an acceptable yield loss level may be found for each producer such that the choice between maintaining insecticide levels without environmental gains and reducing the amount used by one application to avoid environmental damage are equally attractive.

We implemented the model for subjective tradeoff values elicited from farmers through a contingent valuation (CV) scenario for insecticide use. Farmers were asked to numerically rate the importance they place on avoiding risk for eleven environmental goods that could be affected by insecticide use. Then they expressed acceptable yield losses for using one less application of insecticides contingent on the reduction eliminating a moderate risk to the rated amenities.

To estimate the relationship between acceptable yield loss and factors affecting it, we first developed the econometric form from the theoretical model in equation 1. We used a first-order Taylor series approximation of the difference in the *ex ante* indirect utility functions to obtain

$$\Delta \bar{E}\bar{V} = \beta_0 + \delta L + \beta_1 Z + \beta_2 S + \epsilon^* \tag{2}$$

where $\Delta\bar{E}\bar{V}$ is defined as V_p - V_{np}. The unobserved factors that influence yield loss are in the error term as $\epsilon^* = \epsilon_p - \epsilon_{np}$. Equation 2 hypothesizes that yield loss, individual factors and state context factors determine the difference in utility the farmer receives from current and voluntarily

restricted insecticide use.

Setting $\Delta\bar{E}\bar{V} = 0$ represents that the farmer is indifferent between the two choices. When we then solve equation 2 for L, we express this yield loss as a function of the individual and state context factors

$$L = \frac{\beta_0 + \beta_1 Z + \beta_2 S}{\delta} + \epsilon^* \qquad \textbf{(3)}$$

In this form, we can use the data obtained from the CV scenario to econometrically estimate the parameters that describe this relationship and test their statistical significance (Viscusi and Evans, 1990). We used a Tobit model for estimation to account for the possibility that some producers will not trade any yield loss to obtain environmental benefits, resulting in the distribution of yield loss values being truncated at zero.

2.3. SAMPLE DESCRIPTION

To estimate the model, data from 1,138 questionnaires returned in a CV survey of field crop producers in Illinois, Iowa, Nebraska and Ohio were used (Higley and Wintersteen, 1992). Corn and soybeans are the main crops grown in these states. The initial mailing was in early July 1990, and a reminder and duplicate survey form were mailed to each nonrespondent in early August 1990.

Individual characteristics described were years in farming, acres farmed, percentage of income from farming, age and years of formal education. Respondents rated the importance of avoiding insecticide risk for 11 environmental goods using a 10-point Likert scale, with 1 corresponding to "Not Important" and 10 corresponding to "Very Important." This scale offers a simple and easily interpretable measure of risk for survey respondents, and has been validated in other risk perception studies (Eom, 1994).

Mean ratings for environmental goods by category and state are given on Table 1. The mean cumulative ratings were 92.8 in Illinois, 92.7 in Iowa, 93.1 in Nebraska and 88.2 in Ohio, out of a possible total of 110. Greater concern is evident for human health effects and ground water protection, and relatively less for surface water and livestock poisoning or crop damage. The least important amenities to protect from insecticide risk were beneficial insects, wildlife (birds, mammals, fish), native plants and endangered species.

Since individual responses may be influenced by environmental conditions and regulations that vary by state, we supplemented the survey data with two indexes constructed from the 1991-1992 Green Index (Hall and Kerr, 1992). The Green Index ranks states on the basis of 256 indicators of pollution, quality of life, renewable and nonrenewable resource management, human health, environmental policies, and state Congressional voting. We summed the rankings for 256 indicators to obtain an environmental score variable for each state. The lower the value, the better the state ranks. The environmental scores were 7052 for Illinois, 6541 for Iowa, 7001 for Nebraska, and 7411 for Ohio. These compare with a minimum score of 4583 and a maximum score of 8658 for all fifty states.

The index of agricultural pollution is a subset of these indicators, with rankings for 14 indicators of agricultural impacts on soil and water quality, agrichemical use, participation in conservation programs and importance of agriculture to state economy. The agricultural pollution scores were 405 for Illinois, 414 for Iowa, 422 for Nebraska and 342 for Ohio. For all fifty states, the minimum score was 193 and the maximum was 455.

Under the CV scenario, producers indicated acceptable yield loss per acre to avoid moderate risk to the environmental goods by reducing insecticide use by one application on all acreage. Respondents were told the average cost for a single insecticide treatment was from $7 to

$15 per acre before being asked their willingness to pay. They were also asked how much they spent on insecticides and herbicides in 1989, including application costs. These expenditures averaged $18.55 per acre, ranging from an estimated $0.04 to $220 per acre.

The mean acceptable yield loss was $8.25 per acre to avoid moderate risk to environmental goods. By state, the average acceptable losses were $7.96 in Illinois, $8.56 in Iowa, $8.32 in Nebraska and $7.82 in Ohio. The largest value given by respondents in this sample was $40 per acre, and the smallest was $0.

The survey responses show that virtually all producers recognize the importance of environmental risks from insecticides, but some producers do not accept the premise that they should pay to help avoid environmental risks. Thirteen percent of the sample listed an acceptable yield loss of zero, indicating an unwillingness to pay any environmental costs. Higley and Wintersteen (1992) concluded from sample statistics that bias in these values due to a disproportionate number of environmentally concerned producers is unlikely.

3. Results

The definitions of variables used in the model are presented in Table 2. YLDLOSS, the dependent variable in the regression, is the acceptable yield loss. The vector Z in equation 3 is composed of TOTCOST, TOTCOST2, ACRES, ECONINDX, ENVINDX, FARMYR, and EDUC. ECONINDX is an index for six environmental goods that affect yield risk through impacts on farm and human productivity. The goods are surface water, ground water, beneficial insects, harm to livestock/crops, acute toxicity to the farmer and others, and chronic toxicity to the farm family. ENVINDX is an index for five goods that affect risk to life support and quality of life environmental functions. These goods are fish, birds, mammals, native plants, and endangered

species. Both indexes are sums of the importance ratings, so that a respondent who rated all factors as very important (10) would have a value of 60 for ECONINDX and a value of 50 for ENVINDX.

The vector S in equation 3 contains the variables ENVSCOR and AGPOL. These indexes reflect the environmental conditions and agricultural pollution levels in each state. Each producer from a given state has the same values for the two variables, so that any significant variation due to state conditions is detectable. These scores were discussed in the previous section.

Maximum likelihood estimates for the yield loss model are presented in Table 3. Estimated coefficients are interpreted by both sign and statistical significance with respect to their influence on acceptable yield loss. The estimated coefficient on TOTCOST was significant and positive, while that on TOTCOST2 is negative. Farmers who spend more for pesticides are willing to accept higher yield losses to avoid moderate environmental risks, up to a point. Acceptable yield losses for the sample peaked with pesticide expenditures of $89 per acre, then began to decline as expenditures continued to increase. For every additional dollar spent on herbicides and pesticides up to $89, acceptable yield loss increased by $0.010 per acre.

Since there is little variation in crop mix in the four states, there is little chance that large per unit price differences in chemicals are responsible for this result. Farmers who spend more may have better yields and so may be able to tolerate larger yield losses in return for environmental protection. However, the highest expenditures may be correlated with lower environmental concern or belief that more chemicals always increase yield.

ECONINDX was not a significant factor influencing willingness to pay for environmental protection. The mean sample value for ECONINDX was 53.2, very close to the maximum rating of 60. Avoiding risk to environmental goods that have productivity impacts is very important to

farmers, but this concern does not alter acceptable yield losses. By protecting these goods through reduced insecticide use, farmers decrease risk to production factors. They may view this effect as offsetting the voluntary yield loss.

ENVINDX had a significant positive influence on acceptable yield loss. The mean value for ENVINDX was 39.0, compared with a maximum of 50, suggesting less agreement on the importance of these life support factors than the economic factors. Farmers who express strong support for protecting environmental goods are willing to pay more to avoid damage, even though there may be no direct benefit to net returns for the farm. For each one unit increase in importance rating, the acceptable yield loss increases by $0.013.

Estimated coefficients on FARMYR and EDUC were positive and significant. More experienced, better educated farmers accept greater yield losses to avoid environmental risks from insecticides. These farmers risk greater losses in human capital from health effects of environmental damage than less experienced, less educated farmers. More experience and education imply necessary skills and knowledge to adjust crop protection practices while reducing insecticide applications, and greater awareness of the effects on environmental goods. For each additional year of farming experience, acceptable yield loss increases by $0.007 per acre, and another year of education translates to an increase of $0.031.

Neither ENVSCOR nor AGPOL significantly influenced acceptable yield loss. One explanation is that farmers' subjective risk tradeoff is framed without reference to the regulatory and environmental conditions in the state. While farmers may be aware of their state's situation, they do not determine their payments for environmental protection as if they are contributing to state level improvements. Existing state regulations and environmental conditions form a background for producer decisions, but do not make farmers more or less likely to choose

voluntary insecticide reduction.

4. Summary and Conclusions

We used a utility model to demonstrate that farmers are willing to voluntarily reduce insecticide use, accepting yield losses for moderate reduction in environmental risk. The results from the Tobit model indicate that more experienced, better educated farmers, those who spend more on pesticides, and those who more highly rate protection of environmental goods will pay more. Estimation was based on data from 1,138 Midwestern crop farmers, and is generalizable to other producers who share similar characteristics.

An approximation of the total value of environmental protection from insecticide reductions may be obtained by multiplying acreage and the average willingness to pay for moderate risk avoidance. Responses to the yield loss question were predicated on each farmer's crop mix, regardless of the crops grown. Using the average acceptable yield loss for each state, the total value of environmental protection to all farmers in 1989 was $420,330,562 for corn and soybeans, the main crops in Illinois, Iowa, Nebraska and Ohio. That is, farmers were willing to give up over $420 million in yield losses, or about 4 percent of total sales, to guarantee that the eleven environmental goods were protected.

There are several reasons why farmers do not voluntarily reduce chemical use beyond current levels, despite stating that they are willing to do so. First, in the real world, uncertainty about insecticide risks exists, whereas the CV scenario guarantees risk avoidance by reducing insecticide use. Farmers may not believe the risk to environmental goods can be avoided by eliminating a single application, or they may believe current risk levels are low, rather than moderate. Research to determine economic and environmental risks and returns from reduction in insecticide use would provide a credible basis for making choices.

A second factor in the real world is the dominance of regulatory approaches, while voluntary action was the focus of the CV scenario. Farmers who perceive that reducing chemical inputs increases yield risk are significantly less likely to support regulations on use (Lohr et al., 1994). Under voluntary reductions, farmers are able to "buy" environmental protection by "paying" a yield loss, so the exchange is explicit. Under regulations, all farmers "pay" the same amount, but do not necessarily feel they have received the correct level of environmental risk avoidance for the amount paid. Preference-based behavior is an economically efficient solution for farmers. Regulations could then be targeted to situations in which farmers' preferences do not result in socially desired levels of insecticide reduction. In our sample, 87 percent of farmers would be willing to make voluntary reductions.

A third reason why voluntary reductions are not observed as reported in the CV scenario is that farmers may feel they place themselves at a competitive disadvantage if they unilaterally reduce insecticide use. The benefit of risk avoidance is shared by everyone, but producers who reduce chemical use bear the full cost. The CV scenario asked farmers to consider only their willingness to pay, in the absence of any contribution by other farmers.
If they knew others would contribute an equal amount, farmers might be motivated to pay less. This is the situation when a regulation imposes equal costs or equal proportions of costs across all chemical users.

Farmers are willing to pay with yield losses for reduced risk for important environmental goods. Lack of credible information on risk, dominance of regulatory approaches and economic pressures may undercut voluntary reductions in insecticide use. Greater reliance on market-based incentives to voluntarily reduce chemicals would result in more efficient environmental risk reductions.

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