Farmer risk assessment for voluntary insecticide reduction

Luanne Lohr a,*, Timothy Park a, Leon Higley b

a Department of Agricultural and Applied Economics, University of Georgia, Athens, GA 30602, USA
b Department of Entomology, University of Nebraska–Lincoln, Lincoln, NE 68583, USA

Received 11 May 1998; received in revised form 10 September 1998; accepted 7 October 1998

Abstract

We develop a theoretical basis for voluntary reduction in insecticide use, and quantify the subjective value farmers place on reducing environmental risk. The indirect utility model is used to quantify the acceptable financial cost of eliminating one insecticide application in return for avoidance of moderate risk to the environment. The mean valuation in Illinois, Iowa, Nebraska and Ohio, USA, is $8.25 per acre. Acceptable yield loss increases with importance of environmental goods, with formal education and with farming experience. Valuation increases with total expenditure on insecticides up to $89 per acre. Decomposition of the Tobit model used in estimation indicates that voluntary programs should target intensification rather than extensification of participation to maximize effectiveness. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Indirect utility model; Environmental risk valuation; Voluntary insecticide reduction; Tobit model

1. Introduction

Regulatory approaches have had a diminishing payoff in reducing insecticide use in the United States. Actions by the US Environmental Protection Agency reduced applications by 25% in the 1970s, but by less than 1% since 1986 (Benbrook et al., 1996). The benefit–cost ratio of pesticide regulation continues to decline, with increasing resistance of target pests and damage to beneficials driving higher potency chemical use. Active ingredients applied on major row crops, such as corn and soybeans, rose from 1.8 lbs per acre in 1991 to 3.5 lbs per acre in 1995, even as regulatory costs topped $1 billion per year (Benbrook et al., 1996).

With reduced effectiveness of regulation to limit damage from agrichemicals, increased reliance has been placed on voluntary behavior. Policy prescriptions for sustainable agriculture highlight the theoretical efficiency of voluntary approaches supported by information and education about alter-
natives (Council for Agricultural Science and Technology; CAST, 1995). The recently implemented Pesticide Environmental Stewardship Program (US Environmental Protection Agency, 1996) encourages farmers to reduce pesticide risk through financial and technical incentives. Underlying this approach is the belief that farmers perceive the gains in cost savings and environmental benefits compensate for altering practices and undertaking the risk of yield loss. Though fundamental to the success of a voluntary pesticide reduction program, this belief has not been empirically tested. Though the cost of incentives for voluntary programs depends on farmers perceptions, the tradeoffs farmers make when deciding whether to alter current pesticide use have not been quantified. We develop the theoretical basis for voluntary reduction in insecticide use and quantify the subjective value farmers place on reducing environmental risk.

Jaenicke (1997) documents that numerous studies on pesticide reduction choices make assumptions about yield, input costs and market shares from expert opinion or objective data that fail to account for other adjustments farmers could make. The exclusion of lay opinion about risk from chemical reduction is common, yet usually exaggerates yield losses and ignores farmers’ compensating behaviors that could influence these estimates (Jaenicke, 1997; Higley and Wintersteen, 1996). At the same time, the environment-related and production-related benefits from pesticide reduction tend to be undervalued by researchers (Jaenicke, 1997). Examples of the former include effects on wildlife, endangered species and native plants. Examples of the latter include impacts on beneficial insects, livestock, crops and operator health.

Farmers’ subjective valuations of these amenities, along with knowledge and expectations about alternatives, should influence the selection of insect control method. Previous research describes technology adoption as a function of observable characteristics of the farmer, the farm, the technology, information sources and institutional arrangements (D’Souza et al., 1993). Other research presents chemical alternatives and modeled choice as a function of the chemical characteristics and willingness to pay for yield and human health risk reduction (Owens et al., 1997). We examine the underlying risk tradeoffs, including both production and environmental concerns, that drive the choices modeled by other researchers. The empirical outcome, based on data from crop farmers in four Midwestern states in the United States, quantifies farmers’ willingness to engage in environmental effort through voluntary insecticide reduction and suggests program design elements.

2. Valuing risk tradeoffs

Insecticide reduction has two risk consequences for farmers, potential gains in environmental quality and possible yield loss, resulting in monetary loss to the operation. Insecticide use decisions implicitly trade off these risks, balancing expected environmental gains with expected yield loss. We model the tradeoff between environmental benefits and yield loss as though the farmer maximizes his or her underlying utility function. Decisions by the farmer reveal preferences from which a specified utility may be estimated and expectations about risks of costs and benefits from reducing insecticide applications may be deduced. 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 reduction.

The expected cost of alternative activities and the revenue loss due to yield effects of insecticide reduction are quantifiable as the value of yield loss to each farmer. We use this definition of yield loss to refer to the economic risk faced by farmers reducing insecticide use. Any cost savings from reducing chemical use would be counted against the revenue effect of yield loss. Expected cost depends on each farmer’s best alternate insect control, which is known only to that individual. If a farmer is currently using excess insecticide, substitution may not be necessary. Even in this situa-
tion, any reduction from current use is associated with uncertainty, so expected yield loss may still be positive.

Benefit to the farmer of reducing insecticide use is protection of the environment, measured as the subjective rating of importance in protecting amenities from insecticide impacts. This valuation does not depend on insect control choices, only on the farmers’ underlying utility function. The risk tradeoff between cost and benefit of insecticide reduction relies on an accurate valuation of benefits.

Viscusi (1993) highlighted both the value of quasimarket survey information and the limitations of market data in estimating individual preferences for risk reduction. Estimating utility functions using survey data provides information on variability in the value of environmental goods across producers and the producer valuation of nonmarginal changes in risk. By contrast, hedonic market wage studies estimate the average tradeoff of risk and increased wages but provide no information on the impact of individual utility functions. Estimation of utility functions permits explicit consideration of the impact of producer heterogeneity in decision making by incorporating producer characteristics into the model. Fig. 1 illustrates the basic framework of Viscusi’s model using the scenario of the farm producer.

Let \( ABC \) represent the frontier of available farm enterprise returns—environmental risk combinations facing the producer. The producer selects the optimal production point \( B \) from this frontier, where the locus of expected utility (EU) is tangent to the enterprise returns frontier and environmental–economic risk combination \( E_p, Y_p \). Market data and observed prices can provide evidence on the slope of the tangency with the frontier \( ABC \). However, to determine the change in risk due to reduced pesticides, we must be able to obtain the other points on the EU curve, such as at \( E_{np}, Y_{np} \). Quasimarket data may be used to determine this curve, but some problems may arise in such studies.

Diamond and Hausman (1993) comment that in quasimarket studies, individuals have had difficulty placing values on 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. Mitchell and Carson (1989) note that unrealistic attitudes about the affordability and payment vehicle for the perceived benefits of an environmental good also hinder valuation. An individual recognizing the importance of an environmental good may offer a payment that exceeds his or her budget constraint.

Evidence suggests that farmers may be 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) confirm that farmers know their budget constraints and have experiential and science-based data on the yield risk from curtailing pesticide use. Also, farmers have demonstrated greater appreciation of environmental impacts of their decisions, particularly for ground and surface water (Rockwell et al., 1991a). Jaenicke (1997) notes that farmers are aware of the distinction between production-related and environment-related benefits of pesticide reduction and may be expected to value each suitably. Quasimarket valuation provides an appropriate way to measure farmers’ risk tradeoffs and elicit information needed to estimate the underlying utility function that guides insecticide decisions.

Fig. 1. Environmental risk and farmers expected utility locus.
3. Decision framework

The producer’s indirect utility function is defined over environmental goods and the choices of management practices including pesticide applications conditional on environmental risks. Let \( V_p \) be the state-dependent utility function when the producer maintains current applications with the current level of environmental risk at \( e_p \). The indirect utility function depends on the producer’s income level \((Y)\), vectors of the individual’s environmental attitudes \((A)\), the individual’s demographic and farm characteristics \((Z)\) and regulatory and environmental conditions in the grower’s state \((S)\) or

\[
V_p = F(Y, A, Z, S|e_p).
\]  

Let \( V_{np} \) be the state-dependent utility function when the producer chooses a voluntary reduction in pesticide applications associated with reduced risk of environmental impacts to risk level \( e_{np} \). The compensated willingness to pay for the environmental good is derived from the utility difference model as

\[
\]

The acceptable yield loss \((L)\) is the dollar amount that equates the conditional ex ante indirect utility functions for the two choices where \( \Delta V \) is the indirect utility difference. The empirical model for the acceptable yield loss for each producer depends systematically on the variables defined above:

\[
L = \beta_0 + \beta_1 A + \beta_2 Z + \beta_3 S + \eta
\]

Random and unobserved factors that influence yield loss appear in the error term denoted as \( \eta \).

We specify marginal utility of income as constant across states of environmental quality and independent of income. McConnell (1990) notes that income is typically inferred from ranges and subject to differing levels of state and local taxes and its inclusion creates the potential for measurement error. Monetary yield losses associated with reduced pesticides were not expected to significantly alter utility of income derived from farm operations. Econometric tests also confirm that the marginal utility of income is constant, so income is excluded from the monetary yield loss model in Eq. (3).

Viscusi and Evans (1990) estimate a nonlinear least squares model to evaluate the factors influencing elicited wage levels required to compensate for increased risk of chemical exposures. We propose 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 censored at zero.

Eq. (3) indicates through \( \beta_1 \) that acceptable yield loss increases with intensity of environmental attitudes. The more strongly farmers feel about the importance of reducing risk to environmental amenities, the greater their valuation of environmental protection as measured by acceptable yield losses. Greater intensity implies more pro-social attitudes by farmers and suggests greater likelihood of interest in voluntary insecticide reduction programs (Weaver, 1996).

Borjas and Sueyoshi (1994) develop a structural group effects estimator to accurately measure the impact of group-specific or environmental variables that impact individual decisions. Farmers within a state are influenced by a common set of regulatory and environmental conditions. We adapt this method to the Tobit model to develop unbiased and efficient estimates of \( \beta_3 \), the parameters associated with the state-level structural variables contained in vector \( S \).

To assess policy implications of the model, we need to know the marginal effects of significant factors on expected yield loss. As McDonald and Moffitt (1980) show, the Tobit model may be decomposed into two effects attributable to changes in explanatory variables: change in expected yield loss, conditional on positive acceptable yield loss and change in the probability of accepting a yield loss. These effects are given by

\[
\frac{\partial E(L)}{\partial X_i} = \Pr(L > 0) \left[ \frac{\partial E(L|L > 0)}{\partial X_i} \right] + E(L|L > 0) \left[ \frac{\partial \Pr(L > 0)}{\partial X_i} \right].
\]

The first component in Eq. (4) measures the potential for higher acceptable loss, given positive
Table 1
Average ratings of importance in protecting environmental goods from insecticide risk

<table>
<thead>
<tr>
<th>Environmental good</th>
<th>Illinois</th>
<th>Iowa</th>
<th>Nebraska</th>
<th>Ohio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface water (streams, rivers, pond and lakes)</td>
<td>8.7</td>
<td>8.7</td>
<td>8.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Ground water (wells and aquifers)</td>
<td>9.2</td>
<td>9.1</td>
<td>9.3</td>
<td>8.9</td>
</tr>
<tr>
<td>Beneficial insects (honey bees, lady beetles, etc.)</td>
<td>8.1</td>
<td>8.1</td>
<td>8.2</td>
<td>7.9</td>
</tr>
<tr>
<td>Livestock/crop (livestock poisoning, crop damage)</td>
<td>8.6</td>
<td>8.6</td>
<td>8.8</td>
<td>8.2</td>
</tr>
<tr>
<td>Acute human health effects (poisoning)</td>
<td>9.3</td>
<td>9.3</td>
<td>9.6</td>
<td>9.1</td>
</tr>
<tr>
<td>Chronic human health effects (long term)</td>
<td>9.4</td>
<td>9.3</td>
<td>9.6</td>
<td>9.1</td>
</tr>
<tr>
<td>Fish</td>
<td>8.1</td>
<td>8.1</td>
<td>7.9</td>
<td>7.6</td>
</tr>
<tr>
<td>Birds (game and song birds, eagles, hawks, etc.)</td>
<td>7.9</td>
<td>8.0</td>
<td>7.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Mammals (rabbits, deer, etc.)</td>
<td>7.7</td>
<td>7.7</td>
<td>7.7</td>
<td>7.3</td>
</tr>
<tr>
<td>Native plants (flowers, grasses, trees)</td>
<td>7.7</td>
<td>7.8</td>
<td>7.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Endangered species (plants and animals)</td>
<td>7.9</td>
<td>7.8</td>
<td>7.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Total for all goods</td>
<td>92.8</td>
<td>92.7</td>
<td>93.1</td>
<td>88.2</td>
</tr>
<tr>
<td>Number of respondents</td>
<td>304</td>
<td>495</td>
<td>175</td>
<td>164</td>
</tr>
</tbody>
</table>

yield loss, among farmers who are already willing to make the tradeoff. The second component in Eq. (4) measures the change in the probability the producer will accept any positive yield loss, indicating the possibility of increasing the number of farmers voluntarily reducing insecticide use. We compute these effects for the Tobit model using the estimated parameters.

4. Sample description

The decision model is estimated using data from 1138 questionnaires returned in a survey of field crop producers in Illinois, Iowa, Nebraska and Ohio. 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. Of 8000 mailings, 21.8% responded, from which our sample is extracted. Responses by state in our sample are in roughly the same proportion as the mailout. Details of the survey administration are available in Higley and Wintersteen (1996).

Individual characteristics described are acres farmed, years in farming, years of formal education and percentage of income from farming. Respondents rated the importance of avoiding insecticide risk for 11 environmental goods using a ten-point Likert scale, with one corresponding to ‘not important’ and ten corresponding to ‘very important’. This scale offers an easily interpretable measure of risk for survey respondents and has been validated in other risk perception studies (Weaver, 1996).

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 are beneficial insects, wildlife (birds, mammals and fish), native plants and endangered species.

Since individual responses may be influenced by environmental conditions and regulations that vary by state, we supplement the survey data with two indexes constructed from the 1991–1992 Green Index (Hall and Kerr, 1991). 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 obtain an environmental score variable for each state by summing the rankings for 256 indicators, with lower values indicating better
ranks. The environmental scores of 7052 for Illinois, 6541 for Iowa, 7001 for Nebraska, and 7411 for Ohio compare with a minimum score of 4583 and a maximum score of 8658 for all 50 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 of 405 for Illinois, 414 for Iowa, 422 for Nebraska and 342 for Ohio correspond to a minimum score of 193 and a maximum of 455 for all 50 states. We specify both the environmental and agricultural pollution indexes as logarithmic forms in the model.

After rating importance of protecting the environmental amenities, respondents answered an open-ended question on acceptable yield loss for using one less application of insecticides contingent on the reduction eliminating a moderate risk to the rated amenities. The definition of ‘moderate risk’ is based on persistence and toxicity ratings for impacts on water quality and organisms (Higley and Wintersteen, 1992). The elimination of the moderate risk by this action was presented as a certain probability. Background information was provided for the respondents on the average cost for a single insecticide treatment which range from $7 to $15 per acre prior to eliciting the level of acceptable yield loss. They were also asked how much they spent on insecticides and herbicides in 1989, including application costs. These expenditures average $18.55 per acre, ranging from an estimated 0.04–$220 per acre.

The mean acceptable yield loss is $8.25 per acre to avoid moderate risk to environmental goods. By state, the average acceptable losses are $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 is $40 per acre, and the smallest is $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. A total of 13% of our sample listed an acceptable yield loss of zero, indicating they would not pay any environmental costs. Based on sample statistics from producers in the four-state region, there is no evidence of bias in these values due to a disproportionate number of environmentally concerned producers.

As a check on the model, we perform a test for sample selection bias linked to the exclusion of producers who do not report a value for acceptable yield loss in the survey. Approximately 25% of producers recorded missing values for the requested dollar of acceptable yield loss. Excluding these non-respondents from the econometric model does not bias our results if the decision to answer this question is independent of the yield loss reported by respondents. However, if a set of unobserved factors influences both the decision to respond and the actual amount provided, then the Tobit model produces biased estimates for the effects of the explanatory variables. We report a test of sample selection bias in the Tobit model in our results.

5. 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 Eq. (3) is composed of TOTCOST, TOTCOST2, ACRES, FARMYR, and EDUC, while the vector A is ECONINDX and ENVINDX. 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 Eq. (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 are 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 hypothesis of constant marginal utility of income across states of environmental quality variables is first tested to determine if exclusion of income effects from the estimated form in Eq. (3) is appropriate. The likelihood ratio test from the restricted and unrestricted Tobit models yield a calculated \( \chi^2 \) value of 0.169, which does not exceed the critical value of 3.84 for the 95% confidence level. Since the

<p>| Table 2 |
| Description of variables used for choice model |</p>
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>YLDLOSS</td>
<td>Acceptable yield loss to avoid moderate environmental risks ($/acre)</td>
</tr>
<tr>
<td>TOTCOST</td>
<td>Total expenditure on insecticides and herbicides in 1989, including application costs ($/acre)</td>
</tr>
<tr>
<td>TOTCOST2</td>
<td>Square of TOTCOST</td>
</tr>
<tr>
<td>ACRES</td>
<td>Number of acres farmed</td>
</tr>
<tr>
<td>FARMYR</td>
<td>Number of years in farming</td>
</tr>
<tr>
<td>EDUC</td>
<td>Years of formal education</td>
</tr>
<tr>
<td>ECONINDX</td>
<td>Economic importance index (sum of ratings for six factors). Importance of protecting surface water, ground water, beneficial insects, livestock/crops, acute human health effects and chronic human health effects</td>
</tr>
<tr>
<td>ENVINDX</td>
<td>Environmental importance index (sum of ratings for five factors). Importance of protecting fish, birds, mammals, native plants and endangered species</td>
</tr>
<tr>
<td>ENVSCOR</td>
<td>Natural log of environmental score by state (Illinois, Iowa, Nebraska, Ohio)</td>
</tr>
<tr>
<td>AGPOL</td>
<td>Natural log of agricultural pollution score by state</td>
</tr>
</tbody>
</table>

coefficient is not significantly different from zero, the income variable is omitted.

As a specification check on the results, a Tobit model with sample selection bias is also estimated. The selection equation is based on a probit model with the dependent variable equal to one if the producer provided a response to the acceptable yield loss question and zero for non-respondents. The independent variables include the producers individual and farm enterprise characteristics. The estimated coefficient for the correlation between the error terms in the selection equation and the acceptable yield loss model indicates if sample selection bias is present. The estimated correlation coefficient is not significantly different from zero at the 10% level. The Tobit model reveals no evidence of sample selection bias.

The estimated coefficient on TOTCOST is significant and positive, while that on TOTCOST2 is negative, but not significant. Farmers who spend more for insecticides place higher value on moderate risk protection for environmental amenities.
Acceptable yield loss for the sample peaks with insecticide expenditures of $89 per acre, then declines as expenditures continue to increase. Every additional dollar spent on herbicides and insecticides up to $89 increases the risk valuation by $0.010 per acre, based on results from the Tobit model decomposition. Farm records of insecticide expenditures on a county or individual basis can be tracked in US Census of Agriculture surveys. These results confirm that this information is a valid indicator to identify farmers who are willing to reduce insecticide usage in targeted extension and education programs.

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 tolerate larger yield losses in return for environmental protection, or larger expenditures may signal excess insecticide use, suggesting greater willingness to reduce by a single application.

Estimated coefficients on FARMYR and EDUC are positive and significant. More experienced, better educated farmers value risk protection more. 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 substitute crop protection practices for reduced 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.

ECONINDX is not a significant factor influencing valuation of environmental protection. The mean sample value for ECONINDX is 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. As Weaver (1996) notes, these individuals recognize the importance of profitability in their utility functions, but derive benefits from protecting environmental goods that may outweigh production effects.

ENVINDX has a significant positive influence on acceptable yield loss. The mean value for ENVINDX is 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 value damage avoidance more, even if there is 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.

Neither ENVSCOR nor AGPOL significantly influence 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. Similarities across these Midwestern states, shown by the narrowness in range of index scores, could account for the lack of effect across states. Information on individual farmer’s environmental attitudes along with demographic and farm characteristics have a critical role in targeting producers who will adjust behavior and reduce insecticide applications.

The decomposition of the Tobit model reveals that 62% of the total effect of the explanatory variables on changes in acceptable yield loss is attributable to reactions by farmers who already indicated a willingness to reduce insecticides. The remaining 38% of the total effect is due to additional farmers agreeing to reduce chemical use, based on a higher probability of voluntary reduction by all farmers. Thus, while a change in an explanatory variable both stimulates more farmers to voluntarily reduce insecticide use and increases the yield loss acceptable to farmers already willing to reduce chemicals, the latter has a greater effect on the total change in acceptable yield loss.

The dominant share of reductions in insecticide usage is concentrated among producers who indicate an initial willingness to consider any cutbacks. The magnitude of this intensification effect is fairly uniform across producers in all four states surveyed, exceeding 60% for each state. The prob-
ability of inducing new participants in voluntary pesticide reductions is greatest in Ohio, where producers also have the highest average expenditures on insecticides and herbicides.

The decomposition has useful policy implications for targeting incentives and educational training programs to reduce insecticide use by farmers. Farmers who express an initial interest in such a program will participate most intensively and commit to reducing insecticide applications. Recruiting additional farmers to established voluntary programs will have less impact on the total valuation of environmental risk reduction than will adding financial or technical incentives to increase insecticide reduction by already committed farmers. Given that we cannot identify these individuals a priori, policies should assist those who make the initial commitment to voluntary insecticide reductions. The experience of the Farm*A*Syst program supports this proposition. Following nationwide availability of assistance in identifying cost-effective resource management changes, voluntary participation intensity as of 1995 was 30,000 farmers in 29 states, investing an average of $800 per farm in labor and expenditures to reduce water quality risks (Farm*A*Syst National Office, 1997). Participation is expected to increase as nonparticipants observe the environmental and economic advantages accruing to participants.

6. Conclusions

We apply the indirect utility model to demonstrate that farmers are willing to voluntarily reduce insecticide use, valuing moderate reduction in environmental risk in terms of acceptable yield loss. The results from the Tobit model indicate that more experienced, better educated farmers, those who spend more on insecticides, and those who more highly rate protection of environmental goods value reduced environmental risk more highly. Estimation is based on data from 1138 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 valuation of moderate risk avoidance. Using the average acceptable yield loss for each state, the total value of environmental protection to all farmers in 1989 was over $420 million for corn and soybeans, the main crops in Illinois, Iowa, Nebraska and Ohio. This figure indicates the strength of farmers’ commitment to substituting an alternate insect control method for a single application of insecticide.

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, while in the real world, uncertainty about insecticide risks exists, the scenario guaranteed risk avoidance by curtailing insecticide use. If farmers believe the risk to environmental goods can be avoided by eliminating a single application, or that current risk levels are low, rather than moderate, they are less likely to willingly incur yield losses. Credible research performed in a systems framework is needed to determine economic and environmental risks and returns from reduction in insecticide use (Jaenicke, 1997).

A second factor in the real world is the dominance of regulatory approaches, while voluntary action was the focus of the quasimarket survey. 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. Utility-based voluntary programs induce economically efficient behavior by farmers. Regulations or taxes could then be targeted to situations in which farmers’ preferences do not result in socially desired levels of insecticide reduction (CAST, 1995).

A third reason why voluntary reductions are not observed as reported in the survey is that farmers may be reluctant to place themselves at a perceived competitive disadvantage if they unilaterally reduce insecticide use. Many of the benefits of risk avoidance are shared by everyone, but producers who reduce chemical use bear the full cost. The questionnaire explicitly asked that farmers make their valuations in the absence of contri-
butions by other farmers. In the real world, farmers might assume that everyone contributes an equal amount to the risk reduction effort and thus be motivated to reduce their own insecticide use by less.

Fourth, despite increasing emphasis on voluntary approaches, research and education on alternate insect control methods lags chemical research (Benbrook et al., 1996). Needed information is not uniformly available or accessible to all farmers, given differences in education and farm experience. Interest in learning about alternate insect management may be affected by difficulty and expense of alternatives.

Removing barriers and creating incentives to reduce insecticide use by farmers who already value reduced environmental risk is more cost-effective than attempting to increase the number of farmers who voluntarily comply. Complete approaches require attention to both components. Assistance targeted to concerned farmers intensifies their commitment while increasing the probability of participation by other farmers by showing the net gains from reduced chemical use. Regulations and penalties may then be targeted at changing behavior of farmers unwilling to voluntarily change.

Acknowledgements

We thank Michael Wetzstein, Ted Jaenicke and three anonymous reviewers for comments and suggestions.

References


