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Farmer Demand For Safer Pesticides

Abstract

Voluntary use of safer pesticides by farmers may be encouraged by providing them information about the safety and environmental characteristics of pesticides. A model of farm pesticide choice is developed in order to explore this policy option. Hypotheses about farmer's willingness to pay for safer pesticides are derived.

FARMER DEMAND FOR SAFER PESTICIDES

"Maybe it's silt in the Saginaw Bay. Or maybe it's high nitrate levels or traces of atrazine or alachlor in the family's water well. Farmers know, gut level, these are symptoms of farm practices that, pursued over time, degrade the environment. Not just "the environment," but *their* environment."(Lehnert, 1995)

Introduction

Current pesticide policies focus on reducing the amount of pesticides used and encouraging the adoption of integrated pest management. This approach mistakenly presupposes that all pesticides have similar toxic effects on non-target organisms and the environment. In fact, pesticides vary in their safety attributes. Beach and Carlson (1993) have shown that farmers value water quality and worker safety characteristics in herbicides. Thus, there is potential for obtaining more safety by encouraging the use of safer pesticides and providing more information to farmers on the safety characteristics of pesticides. This paper explores whether voluntary use of safer pesticides by farmers is a viable policy alternative.

It is well known that 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, and adverse effects of other forms of wildlife. Groundwater impacts are particularly important as 90% of rural households and over 50% of the United States population 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 or more pesticides above their Maximum Contaminant 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; Stokes and Brace, 1986; Colborn et al., 1993). Runoff of pesticides into aquatic environments has been estimated to cause 6-14 million fish to be killed annually (Pimentel, et al., 1992). Finally, exposure to pesticides has impaired reproduction in several species of wildlife including alligators and Western gulls (Hileman, 1994).

Much recent research has been done on how much the general public is willing to pay for different groundwater programs (Schultz and Lindsey, 1990; Abdalla et al., 1992; Poe and Bishop, 1992; Jordan and Elnagheeb, 1993). However little effort has been devoted to the possibility that farmers might have incentives to voluntarily reduce environmental damage from pesticides. Results from recent studies indicate that farmers have some willingness to pay to protect their health and groundwater resources from pesticide contamination (Beach and Carlson, 1993; Higley and Wintersteen, 1992). These results suggest the need for more research on farmer's willingness to self-regulate due to concern for their health and/or the environment.

This paper develops a model of farmer behavior which incorporates their health and environmental concerns. Hypotheses about farmer willingness to pay for safer pesticides in terms of health risk and environmental quality are derived from the model. The advantages and disadvantages of two empirical approaches to estimate farmer willingness to pay for safer pesticides are explored. Potential policy implications are also discussed.

Model

Freeman (1993) introduced a life-cycle model of willingness to pay for a change in the probability of death. In it, Freeman 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, U, from consumption, X_t, leisure, L_t, health, H_t, and environmental quality, V_t.

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

Where the following are true:

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

Health is produced via a health production function and is affected by exposure to a pesticide, $E(\rho_t)$, where ρ_t represents the pesticide used. 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 Ω and he/she may also undergo medical treatments, h_t, which mitigate the affects of exposure. In order to make the model more tractable, the level of averting expenditures and medical treatments, as well as environmental quality have not been made functions of the pesticide.

$$H(E(\rho_t), \alpha_t, h_t; \Omega)$$

The following relationships hold:

$$\partial E/\partial \rho_t \geq 0 \quad \partial H_t/\partial E \leq 0$$
$$\partial H_t/\partial \alpha_t \geq 0 \quad \partial H_t/\partial h_t \geq 0$$

Environmental quality is assumed to be a function of the pesticide used, 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 (Hileman, 1994; Edwards, 1993), a negative relationship between environmental quality and pesticide use is assumed.

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 thought of as the probability he/she lives $t-j$ more years. As is the case with all probabilities, the following hold:

$$P_{j,t} > 0, \quad t=j,j+1,...T$$
$$\sum_{t=j}^{T} P_{j,t} = 1$$

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 $t+1$ or later. This survival probability is a function of the same arguments as health: $E(\rho_t)$, α_t, h_t, and Ω. Thus, actions that improve health also influence survival probability. For example, if a safer (to humans) pesticide is used, not only will the individual experience decreased health risk, but also he/she will have a greater chance or surviving each subsequent year.

$$q_{j,t} = \sum_{s=t+1}^{T} P_{j,s}$$
$$q_{j,t}(E(\rho_t), \alpha_t, h_t; \Omega)$$

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 of living $T-j$ more years times the probability of doing so and is given by the following:

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

Where r is the discount rate and is assumed to be the same as the interest rate. It is 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:

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

Where $G(\rho_t)$ is an abatement function. The production function is based on the idea that damage control agents (pesticides) affect production 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.(Lichtenberg and Zilberman, 1986) Pesticides are but one of the many damage control agents used on farms.

Lichtenberg and Zilberman (1986) characterize output as a combination of potential output and losses caused by pests. Losses in output depend on both the environmental conditions 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 (1986), we define $G(\rho_t)$ on the $(0,1)$ interval. When $G=1$, the destructive capacity of the pest is completely eliminated, output is the maximum that can be achieved given the input combination 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 $Q(1, I_t, N_t, \iota_t)$. We assume 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 labor.

$$Y_t = C_{q_t} Q(G(\rho_t), I_t, N_t, \iota_t) - C_{h_t} h_t - C_{\alpha_t} \alpha_t - C_{\rho_t} \rho_t - C_{I_t} I_t - \iota_t w_t$$

Where,

R_t	the unit price of output
Q	output
w_t	the hourly wage paid to farm workers
C_{h_t}	the unit cost of medical treatments and mitigating activities
C_{α_t}	the unit cost of averting and avoidance activities
C_{ρ_t}	the unit cost of the pesticide
C_{I_t}	the unit cost of other productive inputs

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 below

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

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

The individual's problem is to maximize expected lifetime utility:

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

subject to the budget constraint (3), as well as a time constraint:

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

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

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:

$$\mathcal{L} = \sum_{t=j}^{T} (1+r)^{j-t} q_{j,t} U(X_t, L_t, H_t, V_t,)$$
$$+ \lambda_1 \left[\sum_{t=j}^{T} \left[(1+r)^{j-t} q_{j,t} Y_t \right] + \mu - \sum_{t=j}^{T} \left[(1+r)^{j-t} q_{j,t} X_t \right] \right]$$
$$+ \lambda_2 [\tau - L_t - N_t]$$

Where λ_1 and λ_2 are lagrangian multipliers.

Analysis

This model can be used to make inferences about farmer's WTP for pesticides that are safer in terms of health risk and environmental quality. Consider a hypothetical pesticide that has the same efficacy as the one currently used (the abatement function is not affected). 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 WTP, at age j, for a safer pesticide, wtp_λ, can be expressed as (Freeman, 1993):

$$WTP_\rho = \frac{dC_{h_t}}{d\rho_t} = -\frac{d\mathcal{L}/d\rho_t}{d\mathcal{L}/dC_{h_t}}$$

Marginal WTP for a pesticide that is safer to humans but has identical environmental quality effects can then be expressed as:

$$WTP_{health} =$$

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

$$-\frac{\sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}\left(\left(\frac{\partial U}{\partial H_t}\right)\left(\frac{\partial H_t}{\partial E}\right)\left(\frac{\partial E}{\partial \rho_t}\right) - \lambda_1 C_\rho\right)}{\lambda_1\sum_{t=j}^{T}(1+r)^{j-t}q_{j,t}\rho_t}$$

It should be noted that (1) is always non-negative. This expression for WTP can be divided into two parts. The first, can be thought of as a length of life effect (top half of the expression). The safer pesticide 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, can be thought of as a quality of life effect (bottom half of the expression). The reduced exposure to the pesticide also decreases health risk, which, in turn, increases the individual's utility.

Similarly, marginal WTP for a pesticide that is safer to the environment but has identical human health effects is the following:

$$WTP_{env} =$$

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

Again, this expression of WTP is always non-negative. This is comparable to the second half of (1). The increase in environmental quality increases the individual's utility (quality of life).

Finally, marginal WTP for a pesticide that is safer both to the environment and to human is given by the following:

$$WTP_{health,env)} =$$

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

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

Empirical Approaches

Both hedonics and the contingent valuation method (CVM) can be used to estimate all three expressions of WTP for safer pesticides. Beach and Carlson (1993) employed hedonics to derive implicit prices for herbicide characteristics such as toxicity, water quality, and solubility. Their results indicated that these characteristics were significant in explaining herbicide expenditures. The main advantage of the hedonic method is that it is based on actual market data. However, some serious drawbacks do exist. First, implicit price estimates may not be accurate if farmer perceptions of the pesticide attributes are not accurate. Second, omitted variables bias may occur as the researcher decides which characteristics have value. Third, as it is generally necessary to model both supply and demand, implicit prices also reflect pesticide producer's costs. Finally, a pesticide with the attribute(s) of interest must exist.

CVM is often criticized because it is not based on actual market data and may be subject to biases (strategic, starting point, hypothetical). However, these biases can be minimized through careful survey design. CVM allows for the creation of a market specifically for the pesticide characteristics of interest. This method also allows examination of variation in these characteristics. It is also possible to control for farmer perceptions of the pesticide attributes. Unlike the hedonic method, CVM can be used to value a reduction in life expectancy (e.g., from carcinogenic effects of long term exposure to pesticides). Higley and Wintersteen (1992) elicited farmer WTP for reductions in environmental impacts of pesticides. As expected, positive values were associated with avoidance of risk. However, the survey suffered from likely non-response bias (response rate was only 22%) as well as two potentially serious sources of error; a loosely defined hypothetical context and open-ended WTP questions.

CVM appears to be the method most suited to estimating farmer willingness to pay for safer pesticides. In the hopes of improving on the Higley and Wintersteen survey, we plan to use a modification of a CVM format developed by van Ravenswaay and Hoehn (1991). Farmers are presented with the option of purchasing a new, fictional pesticide at a stated price. This pesticide would be exactly like one currently being used on their farm, except the new pesticide presents lower health risk and/or risk to the environment. By switching to the new pesticide, a farmer may decrease his/her risk of cancer by a certain amount or the new pesticide may not leach into groundwater or present a danger to fish or soil invertebrates. Then, questions designed to facilitate the valuation process such as "Would you purchase the new pesticide if it were to cost you $X more per application than the pesticide you currently use?" would be asked. Such questions would be accompanied by others concerning farm and household characteristics and preferences (Carson et al., 1992). The data from the survey could be used to estimate an econometric model of demand for pesticides as a function of perceived safety characteristics, price, and farmer demographics.

Conclusion

Current pesticide policies encourage farmers to reduce pesticide use, but the relative safety of particular pesticides is ignored. Existing research has shown that pesticide attributes such as water quality and user safety have positive implicit prices (Beach and Carlson, 1993). Research has also shown that farmers are willing to pay to avoid environmental damage from pesticides (Higley and Wintersteen, 1992). This suggests farmers may be willing to self-regulate due to concern for the environment and their health when provided with safety information on pesticides. For example, safety information could be required in marketing pesticides or provided via extension programs. In addition, a potential market for new, safer pesticides may exist.

This paper explored the theoretical justification for encouraging farm use of safer pesticides by providing information on their safety characteristics. A model of farmer choice of pesticides is developed which incorporates farmer concerns about heath and the environment. When such concerns are incorporated, a theoretical justification for positive willingness to pay for safer pesticides is obtained. Empirical research is needed to determine if these hypotheses are correct, and, thus whether encouraging self-regulation is a viable policy alternative for reducing health and environmental risks from pesticides.

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