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W-133
BENEFITS AND COSTS OF RESOURCES POLICIES AFFECTING
PUBLIC AND PRIVATE LAND

12TH INTERIM REPORT
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INTRODUCTION

This volume contains the proceedings of the 1999 W-133 Western Regional Project Technical Meeting on "Benefits and Costs of Resource Policies Affecting Public and Private Land." Some papers from W-133 members and friends who could not attend the meeting are also included. The meeting took place February 24th - 26th at the Starr Pass Lodge in Tucson, Arizona. Approximately 50 participants attended the 1999 meeting, are listed on the following page, and came from as far away as Oslo, Norway.

The W-133 regional research project was rechartered in October, 1997. The current project objectives encourage members to address problems associated with: 1.) Benefits and Costs of Agro-environmental Policies; 2.) Benefits Transfer for Groundwater Quality Programs; 3.) Valuing Ecosystem Managment of Forests and Watersheds; and 4.) Valuing Changes in Recreational Access.

Experiment station members at most national land-grant academic institutions constitute the official W-133 project participants. North Dakota State, North Carolina State, and the University of Kentucky proposed joining the group at this year's meeting. W-133's list of academic and other "Friends" has grown, and the Universities of New Mexico and Colorado were particularly well represented at the 1999 W-133 Technical Meeting. The meeting also benefitted from the expertise and participation of scientists from many state and federal agencies including California Fish and Game, the U.S. Department of Agriculture's Economic Research and Forest Services, the U.S. Department of Interior's Fish and Wildlife Service, and the Bureau of Reclamation. In addition, a number of representatives from the nation's top environmental and resource consulting firms attended, some presenting papers at this year's meeting.

This volume is organized around the goals and objectives of the project, but organizing the papers is difficult because of overlapping themes. The last section includes papers that are very important to the methodological work done by W-133 participants, but do not exactly fit one of the objectives. -- I apologize for the lack of consistent pagination in this volume.

On A Personal Note... Any meeting or conference is successful (and fun!) only because of its participants, so I would first like to thank all the people who came and participated in 1999 - listed below. I also want to thank Jerry Fletcher for all his help at this meeting and prior to it, and John Loomis who passed on his knowledge of how to get a meeting like this to work, and who continues to have the funniest little comments to lighten the meetings up. I especially thank Paul Jakus, who helped me to organize this conference and have a lot of fun during it and afterward. Finally, I want to thank Nicki Wieseke for all her help in preparing this volume, and Billye French for administrative support on conference matters.

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P.S. P.F. and J.C. - As far as I can tell, that darn scorpion is still dead!

Water Contamination From Agricultural Chemicals:

Welfare Measures for Chemigation Producers

By P. Joan Poor
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Nebraska producers have been applying agricultural chemicals to their crop land through irrigation systems since the 1960s. Beginning in 1987, environmental regulatory requirements were implemented to prevent water contamination associated with this practice. The purpose of this paper is to use the contingent valuation method to estimate the value chemigation producers place on a reduction in ground and surface water contamination from agricultural chemicals, and to estimate producer surplus associated with a change in environmental quality resulting from the adoption of a new chemigation technology. The analysis shows that a sample of Nebraska certified chemigation applicators indicated positive willingness to pay estimates to reduce water pollution from agricultural chemicals applied through irrigation systems.

Introduction

Negative externalities that arise from the use of agricultural chemicals including groundwater and surface water contamination, have significant environmental as well as human health consequences. Over the past 40 years the increased use of agricultural chemicals has contributed to increases in crop yields and lower production costs, resulting in increased profits. However, the potential hazards associated with the use of these chemicals on the environmental and human health have raised concerns (Fernandez-Cornejo, Jans and Smith, 1998). These concerns have resulted in the increase of environmentally sustainable agricultural production systems such as integrated pest management techniques and more environmentally sound technologies such as organic pesticides. Concurrently, government intervention through regulatory actions to test and licence pesticides has occurred in an effort to ensure that the chemicals that are used are safe for the environment. More efficient application of agricultural chemicals is another method producers can use to reduce not only the risk to their own health but also minimize environmental impacts such as water contamination. One technology that enables producers to optimize (or minimize) chemical usage, reducing costs and environmental impacts, is known as chemigation. Chemigation is a term used for the process of applying agricultural chemicals to field crops through pivot irrigation systems. As long as the chemigation system is equipped with appropriate safety features to guard against water contamination and the applicator is properly trained to operate the system, this technology promotes more efficient use of agricultural chemicals.

Recent empirical studies regarding the adoption of sustainable agricultural technologies often consider whether a producer chooses to adopt these technologies given a set of socio-economic explanatory variables (Mullen et al. 1997; D'Souza et al. 1991; Caswell and Zilberman 1985; Feder and Slade 1984; and Harper et al. 1990). The environmental benefits associated with adoption are often considered separately using non-market valuation techniques. The contingent valuation method has been used to estimate compensating variation measures of producer willingness to pay for an improvement in environmental quality associated with the adoption of safer chemicals (Lohr, Park and Higley 1996; Owens, Swenton, vanRavenswaay 1997 and 1998). In addition, a utility based hedonic analysis of herbicide expenditures was used by Beach and Carlson (1993) to investigate farmer safety and water quality issues associated with chemical prices. This research furthers those efforts and uses the contingent valuation method to ask Nebraska producers who already chemigate within a regulatory setting that requires water contamination prevention devices and training, if they would adopt a new chemigation technology that would further improve environmental quality. By considering only chemigating producers, one can better determine if they are motivated to chemigate solely for profit maximization reasons, or whether their decisions also consider environmental consequences. As such, the purpose of this paper is to use the contingent valuation method to estimate the value chemigating producers place on a reduction in ground and surface water contamination from agricultural chemicals, and to estimate producer surplus associated with a change in environmental quality resulting from the adoption of a new chemigation technology.

Conceptual Framework

First consider a profit maximizing producer who chooses to apply agricultural chemicals to crop land through a pivot irrigation system. Associated with the practice of chemigation is a high probability of both surface and groundwater contamination, through surface spillage and/or back flow through the irrigation well (a negative externality or market failure which has no impact on the profit maximizing producer's production decisions). Regulations requiring producers who practice chemigation to be trained and certified, and to install safety equipment as indicated by a valid permit, act to internalize the water contamination costs. In the presence of such regulations, the practice of chemigation is considered environmentally sustainable. Considering chemigation technology to be a quasi-fixed input or factor of production is reasonable because after the initial investment in the chemigation equipment, the costs associated with certification and well permits are only required if the producer chooses to produce a positive output using this technology. It is also possible that the producer chooses to comply with the regulatory requirements but does not necessarily chemigate every year. The following dual or indirect, restricted profit function appropriately describes the profit maximizing producer:

$$(1) \qquad \pi^R = f(P,W;Z^0) \equiv \max_{y,x_i}\{P \bullet y - w \bullet x_i \;\; / \;\; (y,x_i) feasible\}$$

Where P is the price of the optimal level of a single output y, and w is a vector of prices for the optimal levels of variable inputs x_i and Z^0 the quantity of a quasi fixed or environmental input, or the current level of chemigation technology used by the producer. Equation (1), the indirect restricted profit function, satisfies the following properties:

(1) π^R is convex and continuous in prices, P and w;

(2) π^R is positive or equal to zero. (Non-decreasing in P and non-increasing in w);

(3) π^R is linearly homogeneous in prices P and w for a given Z;

(Cornes 1992; Johansson 1993; Chambers 1988; Kumbhakar and Bhattacharyya 1992; and Tsuneki 1987). Given that the indirect restricted profit function is continuous and differentiable with respect to the prices P and w, Hotelling's Lemma can be used to derive output supply and variable input demand functions as follows:

(2) $$\frac{\partial \pi^R}{\partial P} = y \qquad \text{and} \qquad \nabla_w \pi^R = -x_i$$

Now assume that π^R is also continuously differentiable with respect to Z, such that:

(3) $$\frac{\partial \pi^R}{\partial Z} = \phi$$

where Φ is the shadow price (SP_Z in Figure 1) of the quasi fixed input or the profit maximizing producer's willingness to pay for the use of an extra marginal unit of Z (Tsuneki 1987; and Wear and Newman 1991). This definition can be extended further as per Johansson (1993), in that the producer's willingness to pay represents a change in producer surplus associated with a change in the environmental input or environmental technology, as follows:

(4)

$$\phi = WTP = \pi^R(P,w,Z^1) - \pi^R(P,w,Z^0)$$
$$= \int_{Z^0}^{Z^1} \pi_Z^R dZ$$

Figure 1 illustrates the producer surplus measure where Z is defined as an environmental technology input. The following section provides an empirical application of how data from a contingent valuation survey can be used to estimate producer surplus as a change in a restricted profit function.

Empirical Application: Producer Surplus Estimate for Chemigation Producers in Nebraska

Nebraska is known for its intensely cropped and irrigated farmland. As a result, both ground water and surface water in some parts of the State have become contaminated with agricultural chemicals(USGS 1996). Agricultural chemicals have been applied to Nebraska crop land (as in many other states), through irrigation systems since the 1960s. This chemigation process, has been widespread in Nebraska since the mid 1970s. Chemigation requires unique equipment, as well as applicator training to operate such systems. This process can be advantageous to producers because it provides a cost effective method of applying agricultural chemicals in a relatively uniform and flexible manner. The major draw back is that in the absence of specialized safety equipment and training, chemical back flow into groundwater through irrigation wells can occur and may lead to significant groundwater contamination. Also, lack of training may contribute to accidental discharges of chemicals to the soil surface. Given the presence of this potential water contamination (or negative externality), Nebraska implemented legislation effective January 1, 1987, which placed numerous requirements on producers who choose to apply chemicals through their irrigation systems. These requirements include installation of safety equipment, annual site permits, mandatory equipment inspections, applicator training, testing and certification, accident reporting and penalties for noncompliance (Nebraska Cooperative Extension Service 1985; and Eisenhauer and Buttermore 1991).

In Nebraska those producers using chemigation can be characterized as profit maximizers in the presence of environmental regulations which attempt to internalize the environmental quality costs associated with chemigation. In order to estimate producer surplus or willingness to pay using the restricted indirect profit function framework described above, a hypothetical contingent valuation (CV) scenario was developed and administered to a random sample of certified chemigation applicators in Nebraska. In the spring of 1998, as part of a larger chemigation technology assessment project, 1000 questionnaires containing this hypothetical CV scenario were mailed to individuals trained and certified by the State of Nebraska to apply agricultural chemicals through permitted pivot irrigation systems. Nebraska Department of Environmental Quality personnel who administer the chemigation certification and permitting program, indicated that only about 85% of those people listed as certified chemigators were actual producers, where the remaining survey recipients, who were not able to complete the CV questionnaire, were either Natural Resource Conservation District employees or agricultural chemical sales representatives. Therefore the number of actual chemigating producers who were sent the chemigation questionnaire was assumed to be 850. Taking this calculation into consideration, the survey response rate adjusted for undeliverable and unusable questionnaires was 19%, yielding 152 usable completed questionnaires. No second mailing of the questionnaire occurred because this was part of a larger technology assessment study which did not require additional responses. Although this is considered a very low response rate, it provides a sufficient data set for the given empirical application using the restricted indirect profit function framework.

The CV hypothetical scenario asked producers what they would be willing to pay for a new chemigation technology that maintained current production levels, but reduced water contamination by 50% compared to current practices. The scenario followed a double bounded, dichotomous choice framework where four bid sets were used, described in Table 1. Based on the respondent's answer to the first willing to pay question, they were asked a follow up question in an effort to establish upper and lower bounds on their true willingness to pay for the hypothetical change in water quality. The survey respondents were reminded that this technology does not exist and that their responses in no way reflect whether it will ever be developed. The bid values were presented as an additional dollar cost per year, per irrigation well. The distribution of survey responses is presented in Table 2. Consistent with expectations, as the initial bid value increases, the proportion of respondents who answered YES to the initial bid value declined from 84% for an initial bid of $1 to 55% for an initial bid of $100. Similarly the proportion of respondents who answered NO to the initial bid increased from 17% to 45%, corresponding to the initial bids of $1 and $100, respectively. These results indicate that the survey respondents appear to have seriously considered the bid values when responding to the valuation question.

The econometric model presented in equation (4) represents respondent willingness to pay. Where Z^1 represents the new hypothetical chemigation technology and Z^0 represents the currently used chemigation technology. Willingness to pay or Φ_Z , can then be directly estimated from the CV survey data using Cameron's (1988) approach. We define Φ_Z as follows:

$$Max \phi_{zi} = x_i^{'}\beta + \varepsilon_i \qquad (5)$$

where x_i is a vector of attributes unique to respondent i's production situation and ξ_i is a random error term. It is assumed that willingness to pay is positive and that the underlying willingness to pay commutative distribution G_ξ (•) has a Weibull distribution. There are four response probabilities (P^{YY}, P^{YN}, P^{NN}, P^{NY}) associated with each of the possible responses, (YES-YES, YES-NO, NO-NO, NO-YES), where the initial bid is B and the follow up bid is either B^U (upper bid) or B^L (lower bid) depending on the initial response (Hanemann and Kanninen, 1996). These probabilities yield the following log-likelihood function specification:

$$\ln L = \sum_{i=1}^{S}[I_{YY}^{i}\ln(P_i^{YY}) + I_{YN}^{i}\ln(P_i^{YN}) + I_{NY}^{i}\ln(P_i^{NY}) + I_{NN}^{i}\ln(P_i^{NN})] \qquad (6)$$

where S is the sample size and the term I_{xy} denotes an indicator function equal to 1 when the two responses are xy, and zero otherwise (Hanemann and Kanninen, 1996). Assuming willingness to pay is a non-negative random variable, the relationship can be defined from equation (5) as:

$$\ln(WTP_i) = x_i^{'}\beta + \varepsilon_i \quad i = 1.....S \qquad (7)$$

The regression results from the chemigation producer survey, estimate a mean willingness to pay of $143.23 and a median of $45.59. The regression model was also run including a vector of explanatory variables in an effort to determine those factors which significantly influence a respondent's willingness to pay or the producer surplus welfare estimate. Explanatory variables include the size of the respondents farming operation in terms of irrigated acreage, and years of farming experience as indicated by their age. Variables related to chemigation include equipment costs, years of chemigation experience and the number of permitted irrigation wells they operate. A variable was also included in an effort to determine if the respondent considered whether they were located in an area known for high agricultural chemical contamination, when answering the hypothetical willingness to pay questions. The regression equation was:

(8)

$$\phi_Z = f(\underset{(-)}{TOTAL}, \underset{(-)}{REALCOST}, \underset{(+)}{YRSCHEM}, \underset{(-)}{OLD}, \underset{(+)}{NITRATE}, \underset{(+)}{WELLS})$$

Where TOTAL is the total irrigated acres per respondent; REALCOST is the deflated chemigation equipment cost in $1991 (US Government, 1998); YRSCHEM are the number of years the respondent has chemigated; OLD is a dummy variable which equals one if the respondent is greater than 50 years old; NITRATE is a dummy variable equal to one if the respondent was located in a Natural Resource District known for high nitrate groundwater contamination (Exner and Spalding, 1990) and WELLS is the number of permitted chemigation wells operated by the respondent. These explanatory variables and their corresponding sample means are presented in Table 3.

Expectations regarding the coefficient signs for the explanatory variables are the bracketed terms directly below the variable name in equation (9). It was expected that total irrigated acreage, deflated chemigation equipment costs and the older the respondent, the less likely they are willing to pay for water quality improvements by investing in new chemigation equipment.

Also, the larger the farming operation, and higher the equipment costs, the less likely the producer will be to invest money in environmental quality improvements. The number of years of experience chemigating is expected to be positively related to willingness to pay for water quality improvements via a new chemigation technology compared to those respondents with less experience. Similarly those producers with more permitted chemigation wells are assumed to be more environmentally concerned and thus would be willing to pay more for the new hypothetical technology than those with fewer permitted wills. Finally the NITRATE variable is expected to be positively related to willingness to pay, in that respondents located in areas where groundwater contamination from agricultural chemicals is already a concern, will be likely to pay more to improve water quality than those respondents located in areas where groundwater contamination is less of a problem.

The regression results from equation (9) are presented in Table 4. The coefficient signs were consistent with expectations and all variables except REALCOST and OLD were significant at the 10% level. The results of this empirical application show that Nebraska producers who engage in chemigation on average, are concerned with water contamination from agricultural chemicals in that they indicated a positive willingness to pay to reduce associated water contamination. This conclusion is based on a change in a dual restricted profit function approach to estimate willingness to pay or a producer surplus welfare measure. The results also indicate that producers with more chemigation experience, as well as those located in regions where groundwater contamination from agricultural chemicals is a reported concern, are willing to pay more to reduce contamination than chemigation producers not possessing such attributes. Thus according to these results, profit maximizing chemigation producers do not only use their pivot irrigation systems to apply chemicals in order to maximize profits, but they also are concerned with the potential environmental degradation that may result from this practice.

Conclusions

This paper presents the conceptual framework using a dual restricted profit function, to derive producer surplus welfare estimates associated with a change in environmental quality. An empirical application is presented whereby the contingent valuation method is used to estimate producer surplus of chemigating producers in Nebraska, associated with a reduction in groundwater contamination from agricultural chemicals. The results indicate that producers who are already regulated by an environmental policy are still willing on average, to commit additional money to improving water quality particularly where the water source may be contaminated from agricultural chemicals. Chemigating producers in Nebraska do appear to be concerned with water quality and their impact on it, as well as maintaining viable and profitable agricultural production units. Further research of interest would be to extend the use of contingent valuation analysis in an indirect restricted profit function context, to additional agricultural producers, as one way of understanding producer profit motives verses their concern for the environment and natural resources.

Table 1: Contingent Valuation Scenario Bid Sets

Initial Bid	Upper Bid	Lower Bid
$1.00	$2.00	$0.25
$5.00	$10.00	$2.50
$20.00	$40.00	$10.00
$100.00	$200.00	$50.00

Table 2: Contingent Valuation Scenario Initial Bid and Associated Response Proportions

Initial Bid	%YY	%YN	%NN	%NY	Total Number of Responses
$1	78 (28)	6 (2)	14 (5)	3 (1)	36
$5	67 (24)	14 (5)	6 (2)	14 (5)	36
$20	41 (2)	33 (16)	20 (10)	6 (3)	49
$100	32 (10)	23 (7)	26 (8)	19 (6)	31
Brackets indicate actual number of respondents per category.					

Table 3: Variable Names and Descriptions

Variable Name	Mean	Variable Description
TOTAL	639.14	Total irrigated acres per respondent.
REALCOST	1656.63	Deflated chemigation equipment costs in $1991 (US Government, 1998)
YRSCHEM	9.92	Number of years the respondent has chemigated.
OLD	0.36	Dummy where age is greater than 50 years OLD=1, else OLD=0.
NITRATE	0.82	Dummy equal to 1 if the respondent was located in a Natural Resource District known for high nitrate groundwater contamination (Exner and Spalding, 1990)
WELLS	4.41	Number of permitted chemigation wells operated by the respondent.

Table 4: Equation (9) Regression Results

Variable	Coefficient Estimate	Standard Error
INTERCEPT	2.9095**	1.2069
TOTAL	-0.0024**	0.0013
REALCOST	-0.0002	0.0003
YRSCHEM	0.1178**	0.0603
OLD	-0.3022	0.7136
NITRATE	1.6362*	0.9533
WELLS	0.3612*	0.2106
Scale	1.7919	0.3001
pseudo R-squared	0.52	
Log Likelihood	-88.2684	
* and ** indicate significant levels at 10% and 5%, respectively.		

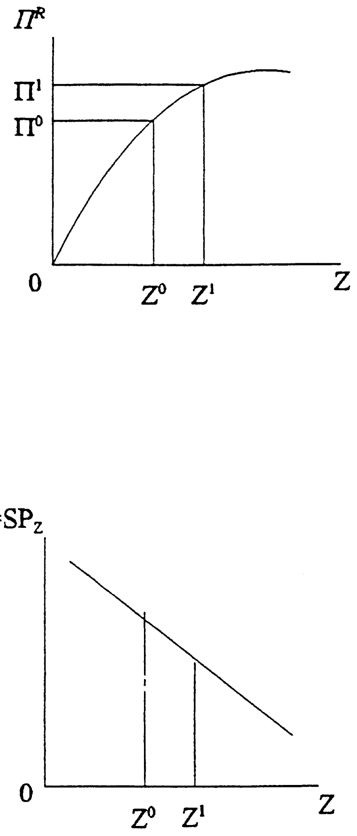

Figure 1:Producer Surplus Diagrams: Given a Change in the Environmental Technology Z.

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