Farm-Level Evaluation of Agricultural and Environmental Policies with an Integrated Modeling System

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Abstract

Concern is growing throughout the United States about environmental and health risks associated with the use of agricultural chemicals. In response to these concerns, public policies designed to alter farming practices and the use of agricultural chemicals are being proposed and implemented. In addition, existing U.S. agricultural policies directed at price stabilization and income support are being reviewed for interdependencies with environmental measures.

This paper provides a farm-level analysis of the interrelationships between the current U.S. commodity program for corn and selected environmentally motivated policies for controlling the use of corn rootworm insecticides. An integrated modeling system is employed that includes economic and biological components. The farm modeled is for Chickasaw County, Iowa. Results show that there are significant opportunities for coordinating agricultural commodity and environmental policies. Policy adjustments are identified that can reduce corn rootworm insecticide use, improving the quality of the environment and limiting health risk, while only modestly affecting certainly equivalent farm income.

Introduction

There is broad evidence of increased concern for environmental and health risks associated with the use of chemicals in U.S. agriculture (Batie 1987; Hoyer et al. 1987; O'Hare et al. 1985). Regulating powers of the U.S. Environmental Protection Agency (USEPA) are being extended through re-registration of pesticides, new drinking water standards, and other measures. Also, many states are enacting laws limiting the use of agricultural chemicals and/or providing funding for research on less chemically dependent cultivation practices, monitoring groundwater quality, and assessing health risks (Wise and Johnson 1989). In fact, it is somewhat surprising that the regulation of agricultural chemicals has progressed so far without more comprehensive analyses of the interrelationships between chemical use, agricultural commodity programs for price stabilization and income support, and farm-level decisions. In many cases it seems as if policies for regulation reflect a limited understanding of possible interdependencies (CARD and USEPA 1989).

Empirical assessments have been developed for the farm-level impacts of U.S. agricultural commodity programs that extend the analysis of impacts to issues of uncertainty. Kramer and Pope (1981) have analyzed commodity program participation using a stochastic dominance model for Kern County (Calif.), demonstrating relationships among program parameters, risk attitudes, and farm size. Musser and Stamoulis (1981) have evaluated commodity programs from the 1977 U.S. Farm Bill using a farm-level, quadratic risk programming model, concluding that for risk-averse Georgia farmers, commodity program participation dominated nonparticipation except at higher levels of expected net returns. An early study by Scott and Baker (1972) used quadratic programming to analyze risk-return trade-offs for Illinois farms, endogenizing commodity program participation.

Recently, these farm-level studies have been expanded in scope, perhaps in response to concerns about environmental and commodity policy trade-offs. For example, Helms, Bailey, and Glover (1987) used a whole-farm simulation model to relate producer preferences on participation in commodity programs to the adoption of tillage practices. They found that a combination of commodity program participation with minimum and no-till practices dominated other alternatives for a typical Utah farm. In a study by McSweeny and Kramer (1986), the integration of commodity program participation and adoption of soil conservation practices within a risk framework was the focus. These authors also examined trade-offs between farm-level soil loss and nutrient (nitrogen and phosphorous) loss. Their findings suggested that cross-compliance between commodity and environmental programs would lead risk-averse southern Virginia farmers to adopt improved soil and nutrient loss control practices.

The present study analyzes farm-level interrelationships between commodity programs and selected environmentally motivated policies for limiting the use of corn rootworm insecticides. A specialized version of an integrated modeling system that incorporates economic decision models and biogeophysical process models was employed for this application (CARD and USEPA 1989). The study addresses the issue of rootworm, the most important corn insect pest in the Midwest (Foster et al. 1986). In crop rotations with one or more years of corn following corn, rootworm infestation often is a problem that requires insecticides or other forms of control. The hypothesis here is that current U.S. commodity programs provide incentives for producers to employ continuous corn rotations and these insecticides; changes in the commodity program could lead to farmer behavior that would reduce environmental and health risk without causing significant losses in certainty equivalent income.

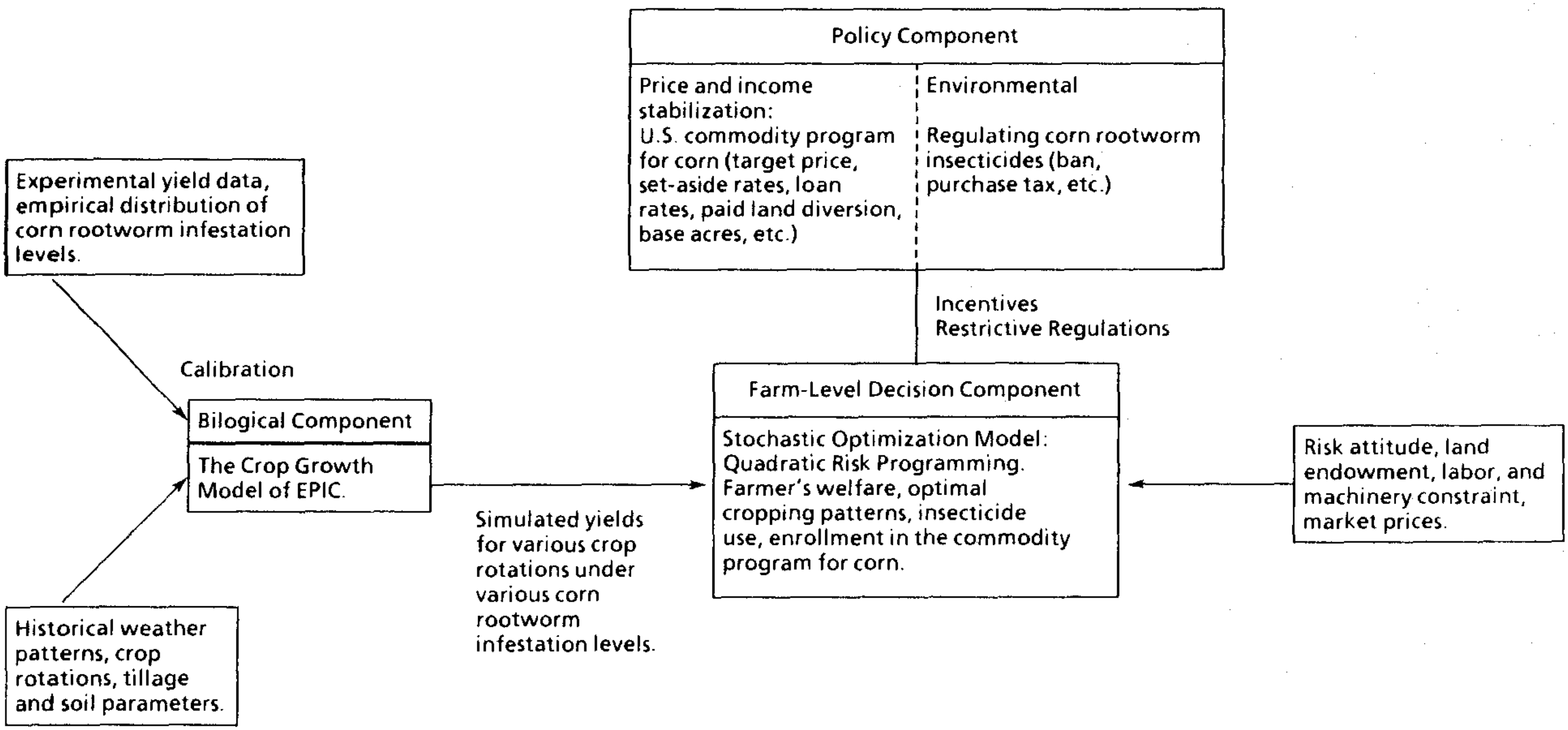
The Integrated Modeling System

The integrated modeling system applied was the Comprehensive Economic Environmental Policy Evaluation System (CEEPES 1989), developed by the Center for Agricultural and Rural Development (CARD) and USEPA. A unique feature of CEEPES is the use of biological, geophysical, and phenological process models as a system, which is further integrated with economic decision and policy models. For the corn rootworm/U.S. commodity program analysis, this system was specialized for farm-level decisions. The specialized version of CEEPES is illustrated in Figure 1.

Policy Component

The policy component identified the agricultural and environmental policy instruments and summarized outcomes of key performance variables. The focus was on the interdependencies between the current U.S. commodity program for corn, set forth in the Food Security Act of 1985 (FSA85), and alternative policies for more directly regulating the use of corn rootworm

Figure 1. Schematic of the Specialized Version of CEEPES



insecticides. The policy component provided incentives and restrictions to the farm-level decision component. Under the FSA85, price and income support and stabilization for corn producers is provided through nonrecourse loans, deficiency payments, paid land diversions, and reduced acreage provisions (Glaser 1986). These program parameters are set by the government prior to planting. Base acreage eligible for enrollment in the program is determined for each farm as a five-year moving average of acres planted plus those set aside under the program for corn. Given this rule, a reduction in the number of corn acres planted plus set aside in one year can reduce the base acres in the following year by one fifth. The base yield, which figures in the calculation of deficiency payments, was frozen in the FSA85, but for this analysis it too is assumed to be determined (as prior to 1986) by a five-year moving average.

Three environmentally motivated policies for limiting the use of corn rootworm insecticides were examined. The first was a complete ban. The second was a tax on the use (purchase) of corn rootworm insecticides levied on the producer. The third maintained base acres if the current level of planted plus idled acres was lower than the base. This third policy--similar to a number of "flexible base" proposals being advanced for the 1990 farm bill--may reduce the acreage planted to corn following corn, thus decreasing the level of insecticide use. A more detailed discussion of impacts of combining the commodity and environmental policies is provided later. The emphasis in the analysis was on the interdependencies between commodity and environmental policies, as well as opportunities for win-win or near win-win outcomes from more coordinated policy actions.

Biological Component

The biological component utilized an existing physiological process model, the Erosion Productivity Impact Calculator (EPIC). EPIC is capable of simulating growth and yield for both annual and perennial plants. EPIC can be operated in time steps by Julian day over an arbitrary number of years, permitting simulation of crop rotations. This feature of EPIC was important for the present analysis in that crop rotations are a way of controlling corn rootworm infestation. EPIC was designed so that required input data (weather, crop, tillage, and soil parameters) are realistically available to most model users. Documentation of EPIC is available in Williams, Jones, and Dyke (1984) and Putman and Dyke (1987).

For operating and calibrating EPIC, we utilized historical weather data and actual yield data. Yields were simulated for commonly observed crop rotations. To account for corn yield reductions due to corn rootworm infestation, EPIC was modified to reflect root damage. The ranges and probabilities of damage were determined from experimental data and consultation with entomology specialists at Iowa State University (Tollefson 1989). Thus, the biological component was used to provide simulated yield distributions for selected rotations and levels of corn rootworm infestation. These yield distributions and infestation levels were in turn used to calculate distributions of net returns for the cropping activities in the farm-level decision component. Thirty-three years of actual weather data were used to estimate these distributions.

Farm-Level Decision Component

The farm-level decision component utilized quadratic risk programming (QRP) to evaluate producer behavior under uncertainty. Among the alternative methods for explicitly modeling risk in farm decision problems, QRP (the mean-variance approach) probably has been the most popular. Freund (1956) was the first to apply QRP for an agricultural firm. Since then, QRP has been applied in many farm-level decision analyses; e.g., Scott and Baker (1972), Jensen and Piedrahita (1979), Musser and Stamoulis (1981), and McSweeny and Kramer (1986).

In matrix notation the standard QRP model can be represented as

$$\max_{\underline{X}}\{\underline{C}^T\underline{X} - \alpha\underline{X}^T\Sigma\underline{X}\}, \tag{1}$$

$$\text{subject to } A\,\underline{X} \le \underline{b}, \tag{2}$$

$$\underline{X} \ge 0, \tag{3}$$

where $\underline{X}$ is the vector of enterprise activity levels; $\underline{C}$ is the vector of expected net returns; Σ is the variance covariance matrix of net returns; α is the coefficient of absolute risk aversion; $\underline{b}$ is a vector of the resource endowments; and A is the matrix of input-output coefficients. It is well known that the quadratic objective function is compatible with the widely accepted expected utility theory only if the farmer's utility function is quadratic, or if the farmer has a negative exponential utility function and the probability distribution of the net returns for the activities is multivariate normal (Freund 1956). However, the studies of Tsiang (1972), Levy and Markowitz (1979), and Meyer (1987) suggest that the mean-variance approach may closely approximate economic behavior based on a wider range of utility functions.

The QRP model activities were developed for production, enrollment in the government program for corn, penalty for loss of corn base, and insecticide supply. The production activities were for selected rotations, a single soil type, and a conventional tillage method. Enrollment activities were for several commonly observed crop sequences. Set-aside requirements, deficiency payments, the nonrecourse loan program, and paid land diversion were included in the simulations. The penalty on loss of corn base activities was specified for several crop sequences. The insecticide supply activity was specified for a standard rootworm insecticide application. The representative farm was endowed with 350 acres of land and subjected to seasonal limits on labor and machinery.

Representative Farm

The specialized version of CEEPES was applied for a typical farm in Nashua, Iowa (Chickasaw County). Crops included in the farm-level analysis were corn (C), soybeans (S), oats (O), and legume hay (L), grown in typical rotations observed in Iowa. Five crop rotations were included in the representative farm model: (1) continuous corn (CC); (2) corn following soybeans (CS); (3) two years of corn following one year of soybeans (CCS); (4) a sequence of corn, soybeans, corn, oats, legume hay (CSCOL); and (5) corn followed by oats, followed by three years of legume hay (COLLL).

Rotations with one or more years of corn following corn were assumed to be subject to rootworm infestation in the absence of corn rootworm insecticides. Following Foster et al. (1986) and consultation with an ISU entomologist (Tollefson 1989), it was determined that corn root damage could be assumed negligible in all crop sequences other than corn following corn (i.e., the CC and CCS rotations). The sources of risks considered were technical risk in yields due to weather and pest infestation, as well as output price risk. These sources of risk were important for conditioning producer decision making in the representative farm model.

Model Specification, Data, and Assumptions

CEEPES was adapted to the production area in Iowa selected for use in illustrating farm-level trade-offs between environmental and agricultural commodity policies. In this section the process models utilized for the analysis are reviewed and the structure required for the policy evaluation exercises is developed.

EPIC

EPIC was calibrated to reflect yield levels in the study area and to simulate impacts of corn rootworm infestation. Historical daily weather data for the years 1955-1987 was used, coupled with plot-level experimental data on rootworm infestations and outcomes on corn yield for the years 1977-1984 in Nashua (Tollefson 1989). Average county soybean, oat, and legume hay yields for years 1977-1987 were used to calibrate EPIC (Iowa Agricultural Statistics 1978-1988). To assess impacts of rootworms on corn yields, EPIC was applied to estimate yield reductions for selected levels of damage. The rootworm damages were reflected in reduced daily water uptake. This approximation of damages was based on results of an EPA-funded study on corn rootworm insecticides (CARD and USEPA 1989).

Four levels of rootworm infestation were selected using the ISU root-rating system. Following Tollefson (1989), ranges of root damage with ratings 1-3, 3-4, 4-5, and 5-6 were mapped into four infestation levels (None, Low, Moderate, Heavy), with probabilities 0.1, 0.4, 0.4, and 0.1, respectively. The estimation of the discrete probability distribution for infestation levels was based on Turpin et al. (1972), as well as on experimental data from Nashua on observed infestations and yield reductions under various infestations (Tollefson 1989). This experimental data also was used to calibrate EPIC and to simulate corn yields for 33 years using the probabilities of infestation. It was assumed that the infestation levels were temporally uncorrelated and independent of weather.

QRP

Historical market prices for each crop year (1955-1987) were obtained from an Iowa State University Extension publication (Futrell 1988). Relevant corn program parameters for the period 1974-1987 were obtained from unpublished ASCS data (1989). Data on variable production costs for the crop sequences were extracted from ISU Extension budgets (Duffy 1987). All prices and costs were expressed in 1987 dollars.

Corn rootworm insecticide costs were not directly included in the net returns for the production activities. Instead, the cost of the insecticide was introduced through a separate activity to facilitate the introduction of the ban and tax. Accounting for the quantity of the chemical applied was in pounds of active ingredients per acre. The recommended rate used was one pound per acre. Insecticide costs per acre were calculated using the price of Counter, the major corn rootworm insecticide in Iowa (Wintersteen and Hartzler 1987).

Production Activities

The time series of yields estimated from EPIC, together with the historical market prices, program parameters, and variable costs of production, were integrated to estimate net returns per acre by production activity and alternative infestation levels. Recall that only corn following corn rotations were subject to rootworm damage. That is, the estimates of net returns were

$$RP_{ij} = \sum_{k=1}^{5} W_{jk}[YLD_{ijk} * MP_{ik} - VC_{ijk}], \qquad (4)$$

where RP_{ij} is the net returns to production activity j in year i (dollars per acre); W_{jk} is the relative share of crop k in rotation j ($\sum_{k=1}^{5} W_{jk} = 1$); YLD_{ijk} is the yield for crop k in rotation j in year i (bushels per acre); MP_{ik} is the market price of crop k in year i (dollars per bushel); VC_{ijk}

is the variable costs of crop k in rotation j in year i (dollars per acre). The expected net returns for each of the production activities were approximated by taking the average over the 33 years.

Enrollment and Penalty Activities

Activities to simulate enrollment in the commodity program for corn and the loss of corn base acres were specified. Penalty activities were forced into the solution only when the level of corn acreage fell below that required to maintain the existing corn base. Both the enrollment and penalty activities were defined for these crop sequences: (1) corn following corn, (2) corn following soybeans, and (3) corn following legume hay.

Since farmers have knowledge of government program parameters prior to planting, the variability of net returns to enrollment derives from uncertainty about market prices and yields. Although expectations of market prices in a given year are likely conditioned upon the level of the program parameters, estimation of this relationship is beyond the scope of this farm-level analysis. A procedure similar to McSweeny and Kramer (1986) was followed. Specifically, the variability of net returns to enrollment, with program parameters certain, was approximated using the target price, loan rates, and paid land diversion payment rate for a single year (1987). These parameters were deflated and used in the calculation of net returns to enrollment for each year from 1974 to 1987. Acreage reduction rates were also as in 1987. For the returns to the enrollment activities, it was assumed that participating producers would take advantage of not only the deficiency payments but also the nonrecourse loan and the paid land diversion program.

The net returns of the enrollment activities were calculated as

$$RE_{ij} = \{(1 - ARP - PLD) * YLD_{ij} * [MAX(LLR_i, MPC_i) - MPC_i]\} \tag{5}$$

$$+ \{(1 - ARP - PLD) * [MAX(TGT_i - MAX(SAP_i, NLR_i), 0)] * BYLD_{ij}\}$$

$$+ (PLD * PLDP_i * BYLD_{ij}) - CVC_i,$$

where RE_{ij} is the return to participating in the corn program of sequence j in year i (dollars per acre of base); ARP is the 1987 set-aside required under the acreage reduction program (percent of total acres enrolled); PLD is the 1987 set-aside required under the voluntary paid land diversion program (percent of total acres enrolled); LLR_i is the 1987 local Chickasaw county loan rate for corn inflated to year i (dollars per bushel); MPC_i is the real local market price for corn in year i (dollars per bushel); TGT_i is the 1987 target price for corn inflated to year i (dollars per bushel); SAP_i is the real national season average market price used to determine the deficiency payments in year i (dollars per bushel); NLR_i is the 1987 national average loan rate for corn inflated to year i (dollars per bushel); $BYLD_{ij}$ is the base yield established by the producer in year i for crop sequence j (bushels per acre); $PLDP_i$ is the 1987 paid land diversion payment rate inflated to year i (dollars per bushel); and CVC_i is the real cost in year i of covering acres set-aside under the acreage reduction and paid land diversion programs (dollars per acre). The expected net returns to the enrollment activities were approximated by the average of all years.

Estimating the distributions of net returns for the penalty activities required the evaluation of the variability of future losses from base acre reduction. Producers are faced with uncertainty about which programs will be implemented and what the values of the associated parameters will be in future years. To approximate the variability in the net present value of the stream of future losses, both sources of uncertainty should be considered. In practice, however, it is difficult to predict if government commodity programs will change in future years. Thus, the latter was estimated using the actual parameter values for the time period 1974-1987.

The annual return to an acre of established corn base was estimated as the return to an acre of corn in the program less the best nonprogram alternative:

$$
\begin{aligned}
BR_{ij} = {} & [(1 - ARP_i - PLD_i) * YLD_{ij} * MAX(MPC_i, LLR_i)] \\
& + \{(1 - ARP_i - PLD_i) * BYLD_{ij} * MAX[TGT_i - MAX(SAP_i, NLR_i), 0]\} \\
& + (PLD_i * PLDP_i * BYLD_{ij}) - CVC_i - NBA_i,
\end{aligned} \tag{6}
$$

where BR_{ij} is the return to an acre of corn base above that of the best nonprogram alternative for sequence j in year i (dollars per acre); and NBA_i is the return to the best nonprogram crop alternative in year i (dollars per acre). The net returns (costs) of the penalty activities were calculated for each year as the net present value of the BR_{ij} over a five-year period. The expected net returns of the penalty activities were approximated as the average over all years.

Constraints

Machinery and labor requirements were subdivided into four seasons--April and May, June and July, August and September, and October and November--and were obtained from CARD/SCS budgets. Estimates of machinery and labor availability were based on typical numbers of workers and machines on a representative Iowa farm, and average number of working hours per season. Constraints on the level of corn base eligible for participation in the farm program were dependent upon the assumed percentage of total acres established as base. A constraint on the amount of rootworm insecticide was also included to simulate the insecticide ban. Balance and transfer rows made up the remainder of the QRP model.

Variance-Covariance Matrix

Using a third-degree polynomial, net returns were regressed on time to detrend the series for each of the three types of activities: production, enrollment and penalty. These detrend net returns were used to estimate the variance-covariance matrix. Thus, it was implicitly assumed that farmers generally are aware of long-run trends in net returns, and only the deviations from the long-run trend are considered random or unpredictable. The calculated variance-covariance matrix and the expected net returns for the production activities and selected enrollment and penalty activities are presented in Table 1.

Table 1. Variance-covariance matrix and expected net returns for the baseline

Activity Number	1	2	3	4	5	6	7	8	9	10	11
Variance-covariance	CC NO INF	CC INF	CCS NO INF	CCS INF	CS	CSCOL	COLLL	PROGRAM C FL S	PROGRAM C FL C NO INF	PENALTY C FL S	PENALTY C FL C NO INF
1	7772										
2	8281	12154									
3	6433	6744	5929								
4	6317	7730	5829	6137							
5	5895	6119	5749	5653	5811						
6	3665	3492	3519	3372	3547	2396					
7	1031	588	1262	1171	1422	1304	1530				
8	−1675	−2036	−1011	−1078	−700	−446	−17	1481			
9	−1681	−2039	−1014	−1080	−701	−448	−19	1486	1491		
10	−195	−42	−199	−194	−288	−216	−220	59	59	155	
11	−265	−284	−239	−272	−285	−208	−169	118	118	100	75
Expected Returns ($/Acre)											
	250.48	179.69	246.51	227.12	234.71	179.12	169.54	153.10	152.94	−76.68	−45.09

INF = Subject to insect infestation
FL = Following
C = Corn
S = Soybeans
O = Oats
L = Legume hay

Several observations can be made based on Table 1. The rotations CC and CCS with insecticide applications dominate the same rotations without insecticides. Accounting for insecticide costs ($8.00/acre for CC and $2.33/acre for CCS), the expected net returns of CC and CCS with insecticides are higher by 35 percent and 7 percent, respectively, than those without insecticides. Moreover, the variances of net returns for these rotations with insecticides are lower by 36 percent and 3 percent, respectively, than those without insecticides. Consequently, CC and CCS without insecticides are expected to be in the optimal QRP solution only if their insecticide-using counterparts are constrained or somehow made less profitable.

Net returns of the production and participation activities are negatively correlated (Table 1). In general, the higher the share of corn in the rotation, the more negative the correlation. Also, the variances of the enrollment activities generally are substantially lower than those of the production activities. These relationships suggest that enrollment in the government program for corn, in combination with the production activities, leads to a reduction in risk.

The penalty activities are negatively correlated with the production activities and positively correlated with the enrollment activities. This implies that higher returns to enrollment in the corn program are associated with higher opportunity costs for loss of base acres. The covariances among the production activities, which all include corn and are subject to the same weather conditions, are always positive. The rotations including legume hay have relatively small covariances with the other rotations. They also have the lowest variances, which tends to increase their attractiveness as the level of risk aversion increases.

Empirical Findings and Policy Implications

The standard for comparison in this analysis is a "baseline" defined to reflect existing agricultural and environmental policies. In the baseline, the target price was set at the 1987 level of $3.03 per bushel, while the acreage reduction rates (ARP) and the paid land diversion (PLD) were set at 20 percent and 10 percent, respectively. Also, 65 percent of the 350 total representative farm acres (228 acres), were assumed eligible for enrollment in the corn program. The cost of corn rootworm insecticide was eight dollars per pound of active ingredient.

Recall that three policies for limiting the use of corn rootworm insecticides were analyzed and compared: a complete ban, a tax on the purchase of insecticides, and the "flexible base." To investigate the role of risk aversion in the empirical analysis, nine levels of the Arrow-Pratt absolute risk aversion coefficient, α, were simulated, ranging from $\alpha = 0.0000$ (risk-neutral) to $\alpha = 0.0004$.[2] Sensitivity analyses were performed for the target price, the ARP set-aside rate, and the corn base acreage. Additional sensitivity analysis involving the target price and ARP set-aside rate provided an opportunity to investigate the possibility of compensating producers for the insecticide ban by offering additional program benefits.

The baseline QRP was solved initially, with the penalty for loss of corn base imposed, for each of the nine levels of risk aversion. The model then was solved at each level of risk aversion incorporating the rootworm insecticide ban and the two levels of insecticide taxes (27 solutions). Following these computations, the penalty on loss of corn base was removed and each of the above alternatives was repeated (36 solutions). The sensitivity analyses performed on the baseline involved two alternative levels of corn base, and one lower level of target price and ARP set-aside rate. Solutions for all levels of risk aversion with and without the penalty on loss of base acres were obtained for each alternative (72 solutions). The same analysis was subsequently performed on the insecticide ban (72 solutions). Finally, the additional sensitivity analysis on the target price and ARP acreage reduction rate was performed for 11 levels of target price and 9 levels of the ARP rate. Solutions were obtained for the baseline and the ban, with and without the penalty imposed at one level of risk aversion (80 solutions). Altogether, the QRP was solved 296 times.

Insecticide Ban

The policy of a complete ban on insecticides had the most notable producer impacts. It is apparent from Figure 2a that the E-V frontiers for the ban are above the frontiers for the baseline, with and without the penalty. This result holds for all levels of expected returns and widens as the risk aversion coefficient, α, increases. In other words, a complete ban on rootworm insecticide application would reduce substantially the expected utility of the farmer.

Figure 2a. Comparison of E-V Frontiers for Baseline and Ban
Corn Base = 65% of total cropland

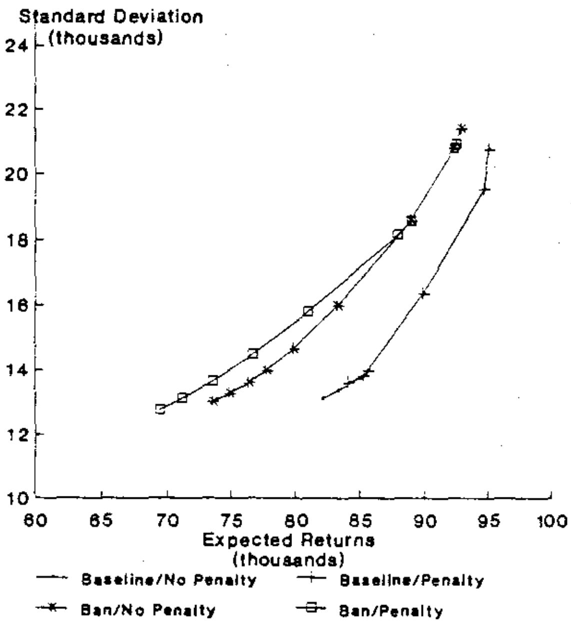


Figure 2b. Comparison of E-V Frontiers for Corn Base = 80% and Ban

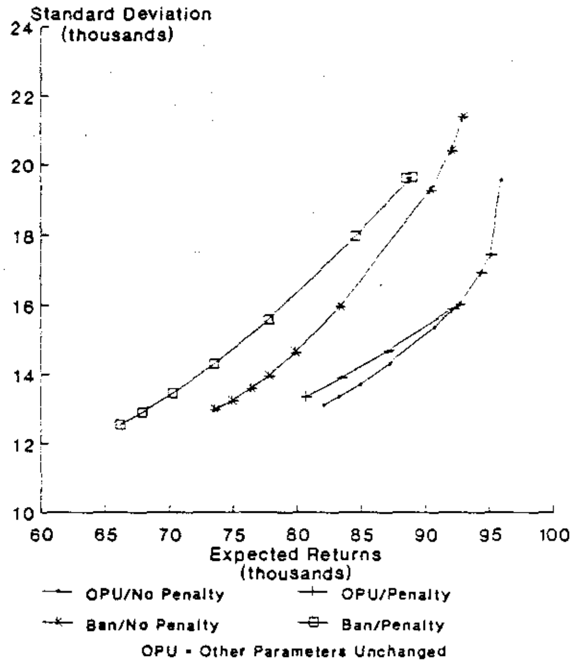
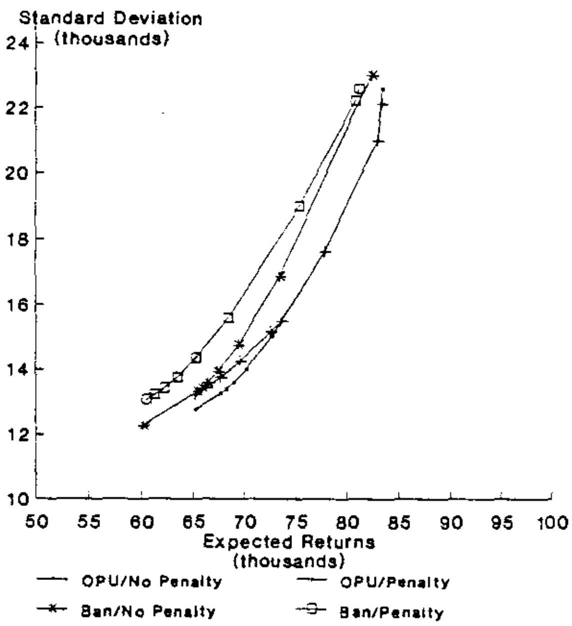
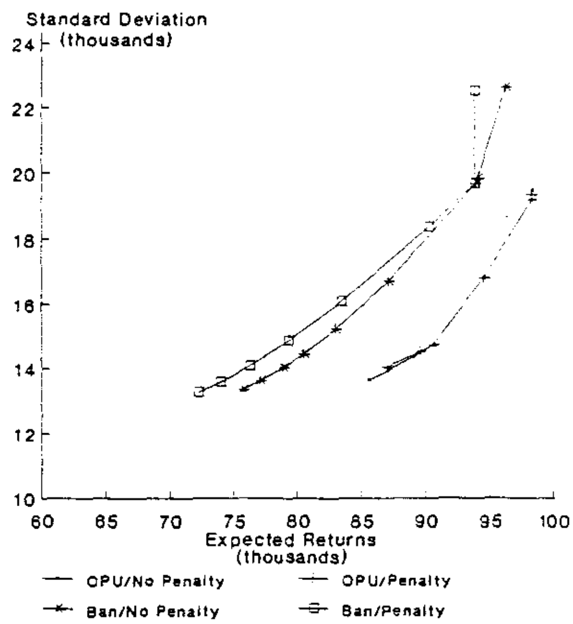


Figure 2c. Comparison of E-V Frontiers for Lower Target Price and Ban
Target Price = $2.50/Bushel



OPU = Other Parameters Unchanged

Figure 2d. Comparison of E-V Frontiers for Lower ARP Set-Aside and Ban
ARP Set-Aside Rate = 10%



OPU = Other Parameters Unchanged

Table 2 presents percentage changes in the optimal values of the objective function when a ban on rootworm is imposed. Clearly, the negative impact of the ban on expected utility increases with the risk aversion coefficient. For the baseline, compared to the ban, reductions of 2.3 percent and 2.8 percent for a risk-neutral farmer ($\alpha = 0.0$) under no-penalty and penalty, respectively, were much smaller (in absolute terms) than the 16.7 percent and 21.7 percent reductions for a risk-averse farmer ($\alpha = 0.0004$). Thus, for the representative farm, the impacts of the complete ban on expected utility varied significantly depending on attitudes toward risk.

Table 3 demonstrates that for $\alpha = 0.0002$, the acres of corn grown and the acres enrolled in the program decreased (except when the corn base was 50 percent of the total acres) with the insecticide ban. At the same time, the summed acres of all other crops (soybeans, oats, and legume hay) increased. These results held whether the penalty for loss of base acres was imposed or not. The observed shifts in crop selection were as expected, since the elimination of the CC and CCS rotations with insecticides made corn relatively less attractive.

Interdependencies between impacts of the complete ban and major parameters of the commodity program for corn can be analyzed (Tables 2 and 3 and Figs. 2a-2d). The greater the opportunity to take advantage of the commodity program (a larger established base), the greater the benefit of participating (a higher target price); the lower the costs of participating (a lower ARP set-aside), the greater the adverse impact of the insecticide ban on farmer expected utility (Table 2).

Table 2. Percentage change in objective function values when a ban on rootworm insecticides is imposed

Alternative	Level of α				
	0	0.0001	0.0002	0.0003	0.0004
Baseline					
Corn Base = 65% of Total Acres					
No Penalty Imposed	-2.3	-6.4	-11.8	-14.3	-16.7
Penalty Imposed	-2.8	-9.3	-15.1	-19.5	-21.7
Scenarios					
Corn Base = 50% of Total Acres					
No Penalty Imposed	-0.2	-3.8	-6.3	-10.7	-14.7
Penalty Imposed	-0.2	-3.8	-6.3	-11.8	-16.3
Corn Base = 80% of Total Acres					
No Penalty Imposed	-3.0	-10.2	-12.8	-14.3	-16.7
Penalty Imposed	-7.0	-12.9	-20.0	-21.2	-22.9
Target Price = $2.50/ bushel					
No Penalty Imposed	-1.2	-4.9	-5.1	-6.2	-7.8
Penalty Imposed	-2.7	-8.0	-9.9	-10.6	-13.1
ARP Set-aside = 10%					
No Penalty Imposed	-2.1	-7.3	-13.1	-15.1	-17.2
Penalty Imposed	-4.5	-10.4	-16.3	-19.9	-22.0
No Program					
No Penalty Imposed	0.0	-3.2	-2.6	-2.4	-2.5

Table 3. Levels of selected indicator variables, for α = 0.0002

Alternative	Corn Grown (acres)	Total of Other Crops Grown (acres)	Enrollment[1] In Corn Program (acres)	Insecticide Applied (pounds[2])
Baseline				
Corn Base = 65% of Total Acres				
No Penalty/OPU[3]	148	122	228	118
Penalty/OPU	148	122	228	118
No Penalty/Ban	121	164	185	0
Penalty/Ban	136	140	209	0
Scenarios				
Corn Base = 50% of Total Acres				
No Penalty/OPU	114	174	175	65
Penalty/OPU	114	174	175	65
No Penalty/Ban	114	174	175	0
Penalty/Ban	114	174	175	0
Corn Base = 80% of Total Acres				
No Penalty/OPU	176	80	270	156
Penalty/OPU	182	70	280	164
No Penalty/Ban	121	163	186	0
Penalty/Ban	135	141	208	0
Target Price = $2.50				
No Penalty/OPU	121	163	187	70
Penalty/OPU	148	122	228	118
No Penalty/Ban	100	196	153	0
Penalty/Ban	116	172	178	0
ARP = 10%				
No Penalty/OPU	171	122	228	140
Penalty/OPU	171	122	228	140
No Penalty/Ban	132	146	175	0
Penalty/Ban	146	123	194	0
No Program				
No Penalty/OPU	116	234	0	35
No Penalty/Ban	105	245	0	0
50% Tax				
No Penalty/OPU	148	122	228	118
Penalty/OPU	148	122	228	118
100% Tax				
No Penalty/OPU	148	122	228	118
Penalty/OPU	148	122	228	118

[1] Area reported includes planted plus area set aside under ARP and PLD.
[2] Quantity reported is in pounds of active ingredient.
[3] OPU = Other parameters unchanged.

The role of eligible acres for enrollment in the corn program is easily demonstrated by an example. For $\alpha = 0.0002$, the impact on certainty equivalent farm income varied from 6.3 percent when 50 percent of the total acres were eligible for enrollment, in both the penalty and no penalty alternatives, to 12.8 percent and 20 percent in the no penalty and penalty alternatives for the 80 percent corn base, respectively. Comparison of Figures 2a and 2b demonstrates that the higher the base acres as a share of total acres, the greater the impact of the insecticide ban on expected utility. The farmers with a higher share of base acres were penalized most, especially when the penalty was imposed. For $\alpha = 0.0002$, with and without penalty imposed, the larger the percentage of base to total acres, the greater the reduction in corn acres grown and corn acres enrolled in the program after the insecticide ban (Table 3). The converse is true for the acreages of other crops.

The relationship of the target price to the ban and the expected utility of farmers can be demonstrated by comparing the impact of the ban on the latter for the baseline target price ($3.03) and the lower target price alternative ($2.50) (Table 2). For $\alpha = 0.0002$, the 5.1 percent (no penalty) and 9.9 percent (penalty) reductions in expected utility from the ban under the lower target price, as compared to the no-ban situation, are significantly smaller than the 11.8 percent (no penalty) and 15.1 percent (penalty) reductions under the baseline target price. Comparison of Figures 2a and 2c demonstrates that the adverse impact of the insecticide ban on expected utility of the producer clearly decreased with the lower target price. A similar comparison can be made between the baseline results and the lower ARP rate. The adverse impact of the ban on expected utility increases only slightly as the costs of enrolling in the program decrease via lower ARP requirements (Table 2 and Figs. 2a, 2d).

The relationships between impacts of the rootworm insecticide ban and the levels of the target price and the ARP set-aside rate on the crop mix can be deduced from Table 3. The lower target price increases the impact of the ban on the area of corn and other crops grown and the amount of corn enrolled in the program when the penalty was imposed. For the lower target price, there was a 22 percent reduction (from 148 acres to 116) in area planted to corn. At the baseline target price, there was an 8 percent reduction (from 148 acres to 136) in the area planted to corn. When base flexibility was introduced, the lower target price had a minimal effect on the impact of the ban. The area of other crops grown increased more (less) under the ban with the lower target price when the penalty was imposed (not imposed) (Table 3). The lower ARP set-aside rate increased the impact of the ban on the area of corn grown as well as corn enrolled in the program regardless of whether the penalty was imposed or not (Table 3).

Finally, for the elimination of the corn program, Table 3 shows that with the ban, the reduction in corn grown was 9 percent (from 116 acres to 105). This can be compared to the baseline, where the ban resulted in an 18 percent reduction (148 to 121) in corn acres. Clearly the impact of the ban on corn produced would be smaller if no program existed.

Likewise, the impact of the ban on the other crops grown would be substantially smaller if the program was eliminated.

Flexible Base

In the baseline of the representative farm model, the commodity program for corn increases corn production and the use of more rotations in which corn follows corn. Thus, greater amounts of insecticides are used to secure program benefits. If reductions in acres of corn grown did not result in base acre reductions, the incentive for rotations of corn following corn would diminish. In the model, this policy change is implemented by the removal of the penalty activities. This base flexibility can be viewed as an indirect environmental policy for regulating insecticide usage.

From Table 3, observe that the flexible base policy had no impact on insecticide use under the 50 percent and 65 percent base acre alternatives, and only a moderate impact (5 percent reduction) when the farm was assumed to have an 80 percent corn base. That is, in the first two corn base alternatives, the assigned base acres are fully utilized in the optimal solution even without the penalty. For the 80 percent alternative, the base acreage available for participation was 3.7 percent greater than the optimal when no penalty was imposed (280 acres vs. 270). Thus, the elimination of the penalty for loss of base acres resulted in a reduction of corn grown and total insecticide use. The combined impact of flexible base and a lower target price on the total level of insecticide use was significant. Total insecticides applied declined nearly

41 percent (from 118 lbs. to 70) when the baseline alternative was compared to the lower target price/no penalty alternative.

In addition to the potential positive environmental impacts of the flexible base, the policy also relaxes a potentially significant constraint for producer behavior. Hence, increases in producer expected utility and adjustments in the crop mix are likely. The percentage changes in the optimal value of the objective function for flexible versus nonflexible base are summarized for the selected values of the program parameters (Table 4). Base flexibility always left unchanged or increased the objective function value. Generally, the negative impact of the penalty on the farmer's expected utility increased with the risk aversion coefficient. These results are illustrated in Figures 2a-2d, which show the E-V frontiers for the penalty situations overlay or are positioned above the frontiers for the no penalty (base flexibility) alternatives.

The gaps between the E-V frontiers under the penalty and no penalty scenarios generally increased with the level of risk aversion. In addition, the gaps were larger under the ban than when no ban was imposed. Table 4 and comparisons of Figures 2a and 2b also show that base flexibility increased producer expected utility more as the percent of total acres eligible for participation increased, especially under the ban. The implication is that the removal of the penalty would be favorable to producers with relatively high levels of established base. When the ban is imposed, removal of the penalty has no additional impact on the use of rootworm insecticides. However, base flexibility does have

Table 4. Percentage change in objective function value given removal of the penalty

Alternative	Level of α				
	0	0.0001	0.0002	0.0003	0.0004
Baseline					
Corn Base = 65% of Total Acres					
No Ban	0.0	0.0	0.0	0.0	1.2
Ban	0.5	0.0	4.0	6.6	7.7
Scenarios					
Corn Base = 50% of Total Acres					
No Ban	0.0	0.0	0.0	0.0	0.0
Ban	0.0	0.0	0.0	1.2	1.9
Corn Base = 80% of Total Acres					
No Ban	0.8	0.0	0.2	3.7	6.3
Ban	5.1	3.1	9.2	12.8	14.8
Target Price = $2.50/ bushel					
No Ban	0.0	0.0	2.0	5.0	8.0
Ban	1.5	3.4	7.4	10.1	14.6
ARP Set-aside = 10%					
No Ban	0.0	0.0	0.0	0.1	1.9
Ban	2.6	0.1	3.8	6.1	8.1
50% Tax	0.0	0.0	0.0	0.0	1.3
100% Tax	0.0	0.0	0.0	0.1	1.5

potential for compensating producers for the losses of welfare associated with a ban.

When the target price was reduced to $2.50 per bushel, compared to the baseline of $3.03, the impact of the flexible base policy on expected utility increased (Table 4). A similar comparison between the baseline results and the lower ARP set-aside rate shows that the impact of flexibility was minimal. When the returns to the program were reduced by the lower target price, producers selected a lower level of corn production only if there was no penalty for loss of future eligibility in the corn program (Table 3).

When no ban was imposed, the flexible base policy left unchanged or decreased the acreage of corn and enrollment in the government program, while increasing the acres of other crops when the ban was imposed. With the removal of the penalty, the percent reduction in corn acreage for the lower target price alternative was larger than that for the baseline. Likewise, the impact of the flexibility on the acreages of other crops and corn enrolled was greater with the lower target price. Base flexibility under the lower ARP set-aside rate had no impact on planted acreages when no ban was imposed.

The impact of flexibility on the optimal crop mix was greatest under the insecticide ban. With the ban, under baseline conditions, the flexible base policy resulted in 11 percent fewer acres (136 to 121) of corn and about the same level of reduction in corn enrolled in the program. This is compared to no reduction when the ban was not imposed. A similar result held for each of the other alternatives, providing support for the argument that current rules for base acres dampen the degree to which producers will respond to a ban by changing cropping patterns.

Taxing Insecticides

Two scenarios were evaluated--one a 50 percent tax and the other a 100 percent tax. It was found that the tax at either level was an ineffective policy instrument for reducing the use of insecticides. For $\alpha = 0.0002$, there was simply no change in the use of rootworm insecticides in response to the tax (Table 3). A comparison of E-V frontiers for the baseline and the 100 percent insecticide tax (Fig. 3) shows that the impact of the 100 percent tax on the level of expected returns and the variability of returns was relatively small for all levels of risk aversion. In addition, neither tax had an effect on the impact of the implementation of the flexible base on expected utility (Table 4). Taxes at these levels will not alter producer behavior or use of insecticides. The taxes simply reduced the farmers' expected utility. Thus, the tax may be viewed as a simple transfer of income.

Additional Observations on the Role of the Corn Program

The empirical results demonstrate that when no ban was imposed, the amount of insecticide application followed closely the amount of corn acreage (Table 3). As the returns to the program enrollment increased and more corn was grown, more rotations with corn following corn were employed (CC and CCS). For the baseline, the amount of rootworm insecticide applied (with the penalty included) was the same as the amount applied with the lower target price (118 pounds). It was 16 percent lower than

Figure 3. Comparison of E-V Frontiers for Baseline and the 100 Percent Rootworm Insecticide Tax

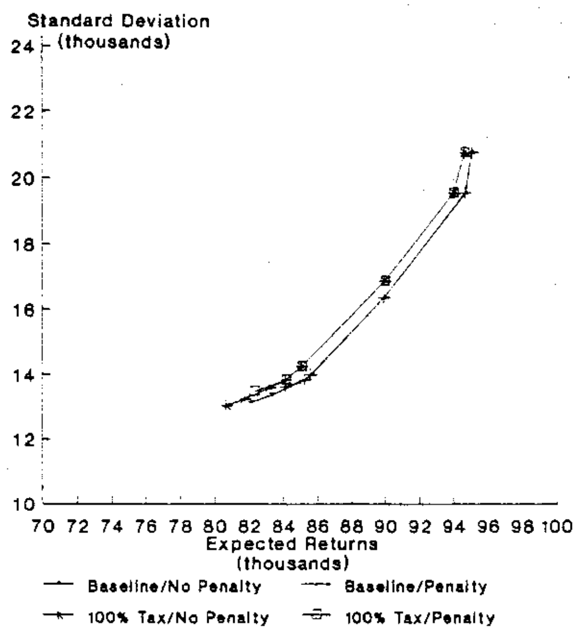
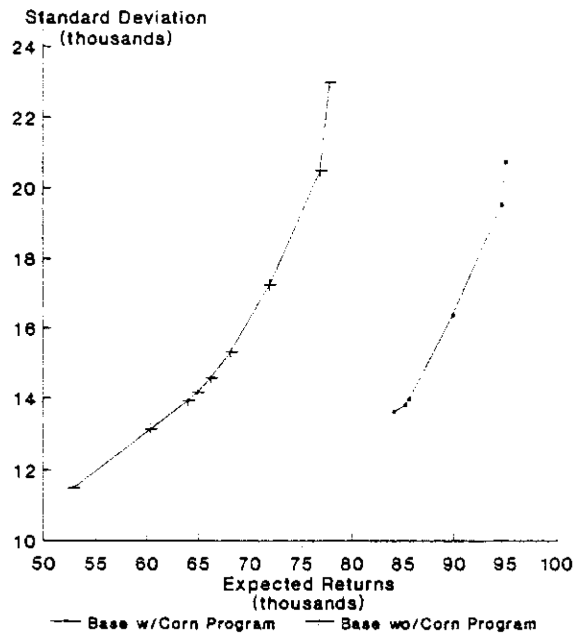


Figure 4. Comparison of E-V Frontiers for Baseline and No Program



the amount applied with the lower ARP set-aside rate (140 pounds). One of the most notable results derives from comparison between the amount of insecticide applied when the program was eliminated and the other alternatives. The reduction from the baseline to the no-program option was over 70 percent (118 to 35 pounds) (Table 3). This strongly supports the argument that the government corn program encourages continuous cropping and use of rootworm insecticides.

The higher the level of base acres, the larger were the quantities of insecticides applied. With 50, 65, and 80 percent of total acres in the corn base, 65, 118, and 164 pounds of active ingredient were applied, respectively, when the penalty was imposed. These fluctuations in the quantities of insecticides applied were associated with changes in acres treated at a constant rate. Changes in the per acre rates were not investigated.

As the target price was lowered, area planted to corn decreased (Table 3). The opposite was the case for the lower ARP set-aside. When the commodity program was eliminated altogether, the total of corn acreage decreased further and the area planted to other crops increased. The decrease in the area of corn grown from the baseline (148 acres) to the no-program option (116 acres) was 22 percent. These results demonstrate the strong impact of the commodity program on producer behavior.

At all levels of risk aversion, the impact of the insecticide ban on farm income was significantly smaller with no program (Table 2). Figure 4 demonstrates the dramatic impact of the corn program on expected returns and the variability of returns. The variability of returns under the program was much lower than without the program. Similar to that reported by Musser and Stamoulis (1981), program participation dominated nonparticipation.

It can be seen that producer expected utility increased at a faster rate with the target price when no ban was imposed (Fig. 5). The ban on insecticides restricted producer ability to take advantage of the higher program payments. At low levels of the target price, the reduction in income caused by a penalty was relatively larger. In fact, the penalty caused a greater reduction in producer expected utility than the ban at the lowest levels of target prices considered ($2.00 and $2.20). This result was expected in that when benefits to the program were low, there was incentive to reduce corn acreage, whereby the penalty was invoked. As the target price increased, the adverse impact of the ban on producer welfare dominated that of the penalty.

The idea of compensating the producer for an insecticide ban by altering program parameters is intriguing. Observe that, to maintain the same level of expected utility with the ban as achieved under the baseline, a target price of approximately $3.50 (with the penalty) could be offered to producers (Fig. 5). A smaller target price of approximately $3.45 would achieve the same result if the flexible base policy were to be introduced.

The reduction in producer welfare as the ARP set-aside rate increased was greater for the no-ban situation (with and without base flexibility) than for the ban (Fig. 6). Thus, we can conclude that as the set-aside rate decreased, thereby decreasing the costs of participation,

Figure 5. Objective Function Values For Baseline and Ban at Alternative Levels of Target Price

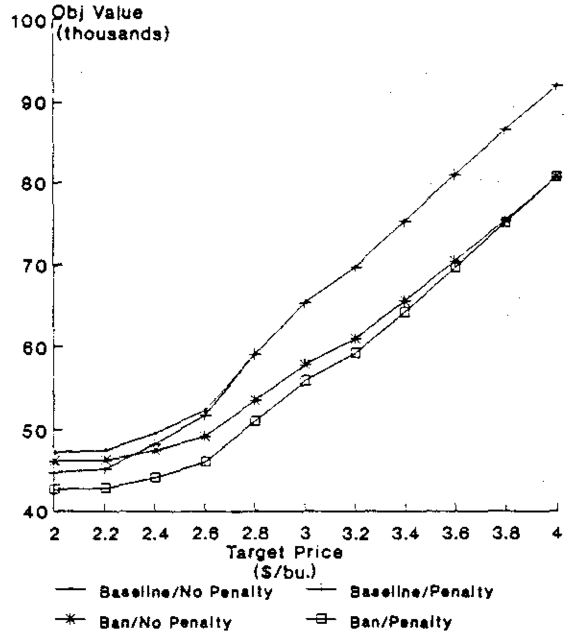
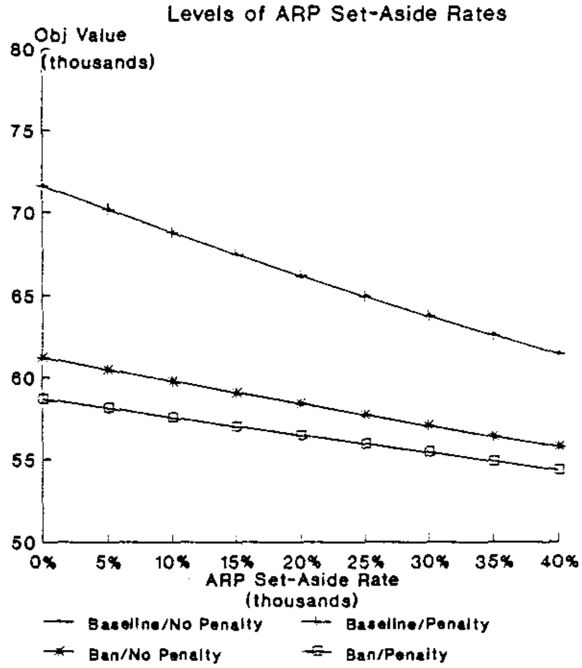


Figure 6. Objective Function Values For Baseline and Ban at Alternative Levels of ARP Set-Aside Rates



the producer was again better able to capture the higher returns of the program when no ban was imposed. There was no level of ARP set-aside that would compensate the producers for an insecticide ban.

Conclusions

This analysis of the implications of organizing commodity and environmental policies in a more coordinated fashion has shown a number of opportunities for improvement. Under certain conditions, the absence of base flexibility for corn was a primary factor driving the use of continuous corn rotations and corn rootworm insecticides. Generally, changes in commodity program parameters that increased the opportunity cost of losing the base resulted in the increased use of corn following corn rotations and corn rootworm insecticides. These increases in the opportunity cost of losing the base involved higher target prices, lower ARP set-aside rates, and a higher ratio of base to total farm acreage.

An additional aspect of the results illustrates the importance of risk aversion in guiding farm-level decisions on insecticide use and cropping patterns. These behavioral parameters were highly tied to commodity program provisions. That is, with increased risk aversion, farmers were inclined to participate in the stabilizing commodity programs. This participation and maintenance of base acreage resulted in corn-after-corn rotations and use of corn rootworm insecticides. Alternative ways of achieving income stability are possible through the purchase and sale of options, increases in diversification, and alternative financial instruments for cushioning uncertainty; e.g., crop insurance.

One of the alternatives investigated in detail was base flexibility. This idea is consistent with a number of proposals for the 1990 farm bill. In general, the conclusion from these exercises was that introduction of a flexible base would, under certain conditions, reduce the use of corn rootworm insecticides. The results suggested that increased flexibility might be tied with a ban or partial ban on the use of corn rootworm insecticide as a way of compensating farmers for associated income losses. Also the target price could be increased to compensate farmers for an insecticide ban. A higher target price with a more flexible base can be viewed as a premium paid to farmers for the ban. By comparing certainty equivalent incomes, a value of the target price that would leave the farmers equally well off could be directly determined.

Clearly, there are significant opportunities for better coordinating environmental and agricultural policies. In fact, for corn rootworm insecticides, agricultural commodity programs have perverse environmental impacts. Our results show that a certainty equivalent income can be maintained while significantly reducing chemical use by modest changes in current commodity programs. Results from these farm-level analyses indicate opportunities for improving the effectiveness of agricultural commodity and environmental policies through coordination.

Endnotes

1. Iowa State University has developed a scale rating root damage from one to six for larval feeding. The rating scale is defined as follows: 1, when no damage or only a few minor feeding scars are evident; 2, when feeding scars are evident but no roots have been eaten to within 1 1/2 inches of the plant; 3, when several roots have been eaten to within 1 1/2 inches of the plant but the equivalent of an entire node of roots has not been destroyed; 4, when one node of roots has been completely destroyed; 5, when two nodes of roots have been completely destroyed; and 6, when three or more nodes of roots have been destroyed.

2. Due to seasonal constraints on labor and machinery, levels of $\alpha > 0.0004$ resulted in idled acreage beyond that required for government program enrollment. Since cropland is typically fully utilized in the study area, solutions for higher levels of α were not considered.

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