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Estimating the Relationship Between Pest Management and Energy Prices, and the Implications for Environmental Damage

by

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A practicing pest management consultant recently suggested that we need to broaden our research emphasis beyond integrated pest management and consider the total crop system. Instead of our more narrow focus, a more appropriate area of investigation would be the economics of integrated crop and pest management (ICPM) systems.[1] We need to integrate the crop production and pest management decisions to determine the most efficient (profitable) way to produce output.

Unfortunately, a major difficulty in the economic assessment of ICPM is the lack of appropriate biological data. Many of the linkages in crop production systems are not well understood or, if understood, reliable parameter estimates are not available. Thus, one of the "emerging issues" of the 1980's should be the development of better ICPM systems through both basic and applied research.

This paper considers alternative pest management systems for corn production in an environment of rising energy prices. First, pest control practices are discussed. Second, historical data are used to estimate derived demand equations for insecticide and herbicide treatment. Third, the impact of rising energy prices on the future demand and supply of pest management systems and on the implied use of insecticides are considered.

Pest Control Practices in Corn Production

To better understand the potential for adjustment to rising energy prices, knowledge of current pest control practices is necessary. The number and percentage of U.S. corn acres treated with both insecticides and herbicides have steadily increased between 1966 and 1976. Insecticide treated acres increased from 33 to 38 percent and herbicide treated acres increased from 57 to 90 percent (USDA, 1968, 1974, 1978). These data are important because they indicate that pest control is an important component of the corn production system, they serve as a crude proxy for the potential environmental hazard created, and they indicate the potential for input substitution as energy prices rise.

Although the national data provide insights into current pest control practices, they provide little information on the potential for ICPM systems. Data for 1977 Iowa corn production, presented in Table 1, are helpful in assessing the potential for improved management systems for corn insect control. Soil insecticides were used on 58 percent of all corn acres and on 91 percent of continuous corn acres. Although chemicals were the predominant control technique, cultural practices (crop rotations) were widely used.

The insecticide treatments in Table 1 were primarily for corn rootworm (CRW) control. Of the 50-51 percent of the Iowa corn acres treated in 1978 and 1979, 44-45 percent were reportedly treated with a CRW insecticide (Becker and Stockdale, 1980). Entomological recommendations suggest that chemical CRW treatments are usually required only on corn following corn rotations. Yet, 25 percent of the corn following soybeans and 43 percent of the corn following other crops received insecticides in 1977.[1,2] Additionally, Taylor (1978) cites studies that indicate that CRW insecticide use on continuous corn could be reduced over 50 percent with little or no loss of yield. The possible overuse of insecticides may be accounted for by the lack of information to interpret indicators of potential damage and by the desire to reduce the variability of yield loss.

Relationship Between Pest Control and Energy Prices

As relative energy prices rise, what adjustments may occur in pesticide use? Historical data are available to estimate separate derived demand equations for insecticide and herbicide treatment in corn production. Cross sectional data for the 10 USDA agricultural regions are pooled for 1966, 1971, and 1976. The empirical specification of the derived demand models for insecticide and herbicide treatment of corn acres is[2]

$$(1)\quad \ln ST_i = a_o + a_1 \ln P_i + a_2 \ln P_F + a_3 \ln y + a_4 \ln SCA + a_5 \ln RE + \ln P_L + e_i$$

where $\ln ST_i$ = log of share of corn acres treated with insecticides or herbicides;

$\ln P_i$ = log of price of insecticides or herbicides;

$\ln P_F$ = log of price of fuel;

$\ln y$ = log of value of corn output per acre;

$\ln SCA$ = log of share of corn acres in cropland acres;

$\ln RE$ = log of lagged production-oriented research and extension expenditures;

$\ln P_L$ = log of farm wage rate;

e_i = error term.

The dependent variable is specified as the share of acres treated with insecticides or herbicides. The insecticide and herbicide treatment data, as well as the data on share of corn acres in cropland acres, are from the USDA pesticide surveys (USDA, 1968, 1974, 1978). The input price indices, P_i and P_F, are regional averages derived from data in "Agricultural Prices - Annual Summary" and P_L is from "Farm Labor". The values of corn output per acre are based upon prices from "Agricultural Prices - Annual Summary" and yields from "Agricultural Statistics." Prices are deflated by the index of all farm production input prices from "Agricultural Statistics." The production-oriented research and extension expenditures are the aggregate value lagged five years from Cline (1975). These expenditures are deflated by an index of average salaries of college and university teachers. Unfortunately, these estimates are not available for corn alone, so the aggregate expenditures are used.

The following relationships are hypothesized for the insecticide and herbicide demand models. First, increasing the price of insecticides or herbicides should reduce the share of acres treated. Second, a positive relationship between fuel prices and herbicide treatments is expected. As energy prices rise, reduced tillage systems become more profitable relative to conventional tillage systems, which use more mechanical (fuel) and less chemical (herbicide) weed control. Even though the net energy saving from reducing tillage and substituting herbicides is not large, it is usually significant. The relationship between fuel prices and insecticide treatment is less certain but hypothesized to be positive. If herbicides and insecticides are treated as joint inputs into reduced tillage, fuel price increases that lead to tillage reductions may increase the demand for insecticide treatment. Also, as energy costs and thus total production costs rise, farmers may apply more insecticides to protect their production cost investment, comparable to a "wealth effect". Third, increasing the value of the crop per acre should increase the demand for treatment. Fourth, ln SCA reflects the intensity of the monocultural environment. A greater share of corn acres in a region will result in more serious insect, especially CRW, and weed problems and thus a greater demand for pest control. Fifth, research and extension expenditures serve as a proxy for the availability of improved information and the efforts to develop alternative pest control techniques.[4] In the case of insecticides, a negative relationship between insecticide treatment and ln RE is hypothesized, given the possible overuse of chemical control and the potential of alternative insect management strategies. The relationship to herbicide treatment is uncertain. Finally, a positive relationship between herbicide treatment and the wage rate is expected. As the price of labor increases, herbicides are substituted for labor in the production process.

Separate weighted least squares regression models for insecticide and herbicide treatment are reported in Table 2. The regressions are weighted by corn acres in the region. Two herbicide demand models are reported, one with and one without the price of labor. The results are generally consistent with the hypothesized relationships and contain some interesting implications about the magnitude of pest control response to rising energy prices. Given the log specification of the models, the estimated coefficients are also elasticity estimates.

The empirical results contain the following price effects. First, rising fuel prices increase the demand for both corn insect and weed control treatments. As fuel prices rise, farmers substitute the relatively cheaper chemical cultivation for fuel and mechanical cultivation. Possibly due to the joint nature of pesticide inputs or to a "wealth effect," a similar relationship occurs in insect control. Second, when the wage rate is not held constant, increasing insecticide and herbicide prices decreases the demand for insecticide and herbicide treatment, respectively. However, the coefficient on insecticide price is not significantly different from zero. Likewise, the herbicide price coefficient is not statistically different from zero if the wage rate is held constant. Third, when the wage rate is included in the herbicide model, it has a positive impact on the demand for chemical weed control, implying a labor-herbicide substitution.

Increasing the value of the crop per acre increases the demand for both insecticide and herbicide treatment. The elasticity is greater for insecticides and reflects, not unexpectedly, the increased demand for crop protection as crop value increases. Increasing the concentration of corn production in a region has a positive and significant impact on weed control problems. Although the coefficient on the share of corn acres has a positive sign in the insecticide demand model, surprisingly, it is not statistically significant.

Finally, lagged research and extension expenditures have a negative impact on the demand for insecticide and herbicide use. This variable reflects the impacts of both improved alternatives for pest control and improved knowledge of pest control needs. Although it does not allow us to determine the substitution possibilities between information and energy in corn production systems, it does indicate that information and alternative pest control strategies are potentially substitutable for chemical control in corn production. This result is more significant in corn insect control where evidence of potential overuse exists.

The results in Table 2 may be a better indicator of what has happened than of what is going to happen as improved ICPM systems evolve for corn production. Such management systems will likely substitute information for chemicals, especially in insect control. To illustrate future corn pest management choices as energy prices rise, the tradeoffs between alternative systems for corn rootworm control will be evaluated, including the impact of rising fuel prices on the cost of supplying pest monitoring services, and on the demand for alternative pest control techniques.

Impact of Energy Prices on Pest Monitoring Costs

Although many pest information services are initially funded by public or private grants, eventually the services must switch to a more permanent funding source (e.g., Extension Service) or become a self-sustaining private enterprise. Given the limited pest monitoring activities currently occurring in corn production, actual monitoring cost data are not available. Also, few studies of the cost of producing pest management information in other crops are available (Grube and Carlson, 1978; Hall, et al., 1975).

To assess the cost of supplying pest monitoring services and to estimate the impact of rising fuel prices, the following pest monitoring cost model is employed:

$$M = \{[ng + (n+1)(1-g)]\ [m(v + f + .05\ w) + wt] + OC\}/a \quad (2)$$

where M = pest monitoring costs per acre;

n = trips to fields that exceed the threshold infestation level;

g = probability of a field exceeding the threshold level;

v = vehicle cost per mile;

f = fuel cost per mile;

m = average distance to participating fields (miles);

w = wage rate paid to scouts;

t = 1.6 + .0067 (a - 40) = sampling time per field of 40 acres or more (Steffe, 1979);

OC = overhead cost of monitoring service per field;

a = acres per field.

In constructing this model, it is assumed that the probability of fields exceeding the threshold infestation can be determined and that nonthreshold fields require an additional sampling.

To derive estimates of the impacts of rising fuel prices on the per acre cost of supplying pest monitoring services, the following parameter values are specified: n = 3, g = .5, v = .21, w = \$5.00, OC = \$15, m = 15, and a = 40. At fuel costs of \$1.00, \$2.00, and \$3.00 per gallon, the costs of supplying monitoring services equal \$1.81, \$1.94, and \$2.07 per acre, respectively.

Fuel costs do not significantly affect the costs of supplying monitoring services to corn producers. More profound cost impacts will result from comparable relative changes in other cost components including program participation (i.e., reducing average distance to fields), wage rates paid to scouts, and trips to fields. Likewise, the rise in monitoring costs due to energy price rises will be overshadowed by the increase in insecticide costs due to rising energy costs. A doubling of fuel costs will increase scouting costs approximately 5-10 percent, but the expected rise in insecticide prices would be more significant (Pidgeon, 1977).

Pest Management Choices With Rising Energy Prices

To evaluate the impact of fuel costs on the choice of CRW management in corn production, the cost of supplying monitoring services, M, is included in the profit function specification

$$(3) \quad y_j = \frac{\sum_{i=1}^{n} [p_i(1-s_j)\, Y_i - C_i - M_{ij} - I_{ij} - F_i - N_i]}{n}$$

where y_j = profit per acre for ICPM strategy j;

p_i = price per unit for $crop_i$;

s_j = expected corn yield loss due to CRW damage for ICPM stragegy j;

Y_i = expected yield per acre for crop i assuming no CRW damage;

C_i = costs of production per acre for crop i excluding fuel, fertilizer, pest control, and land charge;

M_{ij} = pest monitoring costs per acre for crop i with ICPM strategy j;

I_{ij} = insecticide costs per acre for crop i with ICPM strategy j;

F_i = fuel costs per acre for crop i;

N_i = fertilizer costs per acre for crop i;

n = number of crops in rotation.

This specification of the profit (net returns) function is used to simulate the impact of changing fuel prices on the ICPM choice at the farm level. The model is designed to incorporate the impact of rising fuel prices on insecticide, fertilizer, and pest monitoring costs as well. For simplicity, we consider only a limited range of pest control alternatives--soil insecticide, crop rotation, and monitoring with treatment-as-needed. Although other biological, cultural, and adult control techniques are possible alternatives, the cases considered provide an informative illustration of the impacts of rising energy prices on ICPM choices.

The empirical data used in the model are from unpublished sources. The enterprise budget data are from Extension Service circulars of Iowa State University and from U.S. Department of Agriculture (1976). Additionally, the following assumptions are utilized: (1) corn price: $2.50/bu; (2) soybean price: $6.25/bu; (3) corn yield: 120 bu/acre; (4) soybean yield: 36 bu/acre. The yield loss assumptions are based upon insecticide field evaluation studies from the Corn Belt states. The impact of energy price rises on fertilizer and pesticide prices are based on Pidgeon (1977).

Seven crop and pest management systems are considered in the analysis. Table 3 lists the strategies and reports the results of the model runs for 1.0, 1.5, 2.0, and 2.5 times current energy prices. Under current fuel prices,CC-M is the most profitable crop and pest management alternative, but only slightly more profitable than the CC-I (prophylatic control) alternative. But as energy prices rise, some interesting adjustments occur in the profitability of control alternatives. First, monitoring becomes more profitable relative to prophylactic soil insecticide treatment on the CC and CCS rotations. Second, the cultural control systems (CS) become more profitable than CC-I and CC-M as energy prices continue to rise.

A couple caveats are in order. First, we have assumed constant relative prices for corn and soybeans. If the relative price of corn increases with rising energy costs, the CC rotation may remain more profitable. Yet this will encourage the substitution of pest monitoring and chemicals-as-needed for cultural practices. Even though the environmental implications of CC-M may not be as positive as the crop rotation alternatives, it will encourage a substitution away from prophylactic soil insecticide treatments and reduce chemical use. Second, the model is based upon a number of assumptions concerning monitoring costs, yields, yield losses, input costs, and output prices. If these assumptions are inaccurate for particular situations or if certain coefficients change over time, shifts in the profitability of alternative ICPM systems may result. Third, we have ignored the impact of a farmer's risk preference on the choice of pest control technology. If a producer exhibits risk averse behavior, the prophylactic soil insecticide treatment may be preferred even if profits are lower (Miranowski, 1979; Miranowski, et al., 1974).

Conclusions

Based upon this analysis, it is reasonable to conclude that as energy prices rise: (1) weed and insect control will be substituted for fuel inputs in corn production; (2) information (monitoring) services will be substituted for insecticide inputs in corn production; (3) systems analysis provides a useful framework for assessing the impacts of rising fuel costs on the choice of management strategies for CRW control; and (4) environmental quality impacts are ambiguous because we cannot ascertain if the pesticide for energy substitution will be offset by the information for pesticide substitution in the pest control production function.

Table 1. Acres of Corn Treated With Soil Insecticides in Iowa, 1977

	Corn following corn	Corn following soybeans	Corn following other crops	Total acres treated
Total planted ('000 acres)	6261	5886	1354	13,500
Total treated ('000 acres)	5696	1492	579	7,766
Percent treated (%)	91	25	43	58

Source: Jennings and Stockdale (1978).

Table 2. Estimates of the Demand Equations for Insecticide and Herbicide Treatment of Corn Acres

Exogenous variables	Insecticide treatment (1) ln ST_I	Herbicide treatment (2) ln ST_H	(3) ln ST_H
Constant	-47.50	-9.14	-7.69
	(-2.87)	(-1.66)	(-1.64)
ln P_i	-.78	-.75	.03
	(-.53)	(-4.03)	(.10)
ln P_F	15.17	4.42	3.99
	(2.96)	(2.63)	(2.79)
ln P_L			1.89
			(3.22)
ln y	2.97	.69	.27
	(3.27)	(2.36)	(.97)
ln SCA	.19	.22	.22
	(.73)	(2.57)	(3.06)
ln RE	-1.43	-.44	-.34
	(-1.66)	(-1.58)	(-1.39)
R^2	.36	.67	.77
Obs	30	30	30

[a]t-statistics in parentheses.

Table 3. Net Returns Under Alternative Crop and Pest Management Strategies for Corn With Rising Energy Costs

Pest control strategy	Net Returns[1] ($/acre) 1.0X Fuel costs	1.5X Fuel Costs	2.0X Fuel Costs	2.5X Fuel Costs
CC[2] - N[3]	112	99	86	72
CC - I[4]	121	107	93	79
CC - M[5]	122	109	95	81
CS - N	117	106	96	86
CCS - N	112	100	88	77
CCS - I	115	103	91	80
CCS - M	115	103	92	81

[1]Including returns to the land input.

[2]CC - continuous corn; CS - corn-soybean rotation; CCS - corn-corn-soybean rotation.

[3]N - no CRW control regardless of need.

[4]I - CRW soil insecticide applied regardless of need.

[5]M - pest monitoring program with insecticide only as needed.

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Footnotes

John A. Miranowski is an associate professor, Department of Economics, Iowa State University, Journal Paper No. J-9970 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 2368. Without implicating them, helpful comments on an earlier draft of this paper were received from Otto Doering, Wallace Huffman, and Katherine Reichelderfer.

[1]The components of private crop management services may include pest, fertility, water, and soil management as well as other input decisions. Yet, the key input is improved information to assist in decision making.

[2]As Katherine Reichelderfer suggests in her comments, the levels of pest infestation should be included as independent variables in the production function and in the derived demand equations. Generally, historical data on pest infestation in corn production are unavailable.

[3]These alternatives may include breeding genetic resistance, changing cultural practices, developing biological controls, and implementing pest monitoring schemes.

[4]The model treats pest control as an aggregate input, which includes chemical, biological, cultural, and informational components. To provide estimates of quantities demanded and price elasticities of the pest control components, weak separability could be imposed on the aggregate pest control input and a two stage estimation procedure could be employed if the necessary data were available.