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## PEST INFORMATION MARKETS AND INTEGRATED PEST MANAGEMENT

Michael E. Wetzstein

Integrated pest management (IPM) programs vary from employing field scouts to planting trap crops, as inputs in production, to control crop losses. Scouts provide pest information, helping to determine the need for pesticide applications. This increased information may indicate a reduction of periodic application, which would diminish the negative external effects that such treatments have on environmental quality.

Recent research in this area has determined the need for pest information (Regev et al.) and the rationale for established information markets (Feder). Currently, such sources exist throughout the United States, and both public and private consultants supply information to agricultural producers.

Regev et al. conclude that these unregulated markets will not yield an optimal allocation of resources. Information provided to one agricultural producer may be readily applied by another producer at zero marginal input cost. In an unregulated market, this positive external effect is not considered in the selling price of the information. Thus, in evaluating pest information programs, the benefits received from them may be understated. As a result, increased attention is being placed on accounting for this external effect (Smith). This paper investigates the market for pest information and discusses whether regulated markets would be more efficient than would unregulated markets.

In the first section, pest information characteristics are investigated in order to determine the effects of this input on production. This information will be useful to producers who employ the information (participants), as well as those who receive a positive external effect (nonparticipants) from the participating producers. Given the characteristics of pest information, a model is then developed to account for pest information and risk preference in a producer's decision function. The final section summarizes the results and explores the implications of unregulated versus regulated markets for pest information.

### AN OPTIONAL JOINT-IMPACT COMMODITY

Pest information is currently being provided in a number of forms. Producers may pay private or public consultants for pest information, or they may receive it as a service from a governmental agency, for example, the Cooperative Extension Service.<sup>1</sup> Investigation into the supply of information reveals that it is characterized as a joint impact commodity.<sup>2</sup> That is, other agricultural producers can utilize the information obtained from a producer who acquires the information (the participant) without subtracting from the participant's utility. A nonparticipant may obtain the participant's information from a county extension agent, by attending extension or other local meetings, or by talking directly to the participant. Thus, participation by a producer increases the information available to nonparticipating producers with regard to optimal timing and application of pesticides.

Pest information possesses joint-impact characteristics and is also characterized by asymmetry. Participants' information affects nonparticipants utility, but nonparticipants' actions do not affect participants' utility. This assumption is reasonable for a given season if it is assumed that intraseasonal pest migration between fields is negligible. However, in terms of an interseasonal perspective, a pesticide management program by one producer may affect pest population dynamics or resistance for the region as a whole (Hueth and Regev). Information in this case exhibits a symmetrical joint effect.

Pest information obtained by nonparticipants from participants is not directly related to a nonparticipant's production process. The information may not be a perfect substitute for data that nonparticipants would have obtained if they were participants, and nonparticipants may discount the available information from participants in their utility function. Less discounting results in greater substitution and degree of jointness. Pest information is also an optional joint-impact commodity in that the cost of not using it is zero.

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<sup>1</sup> It is assumed in this paper that private consultants are not agents for pesticide producers. For a discussion of private consultants related to pesticide producers, refer to Feder, Hall.

<sup>2</sup> Joint-impact commodities have often been referred to in economic literature as public goods, consumption externality, non-rivalness in consumption. For a composite discussion of these terms, refer to Schmid.

That is, information available by participants can potentially enter nonparticipants utility functions; however, it may not actually do so either because of possible exclusion or avoidance. Thus, nonparticipants have the option of using or not using participants' information, provided that participants do not attempt to suppress it.

## PEST INFORMATION MODEL

Incorporating the above characteristics of pest information inputs into economic theory yields valuable policy insights for pest management. In a partial equilibrium framework, individual producer's production and cost functions are presented to analyze the role of prices in pest information allocation.

Profit,  $\pi$ , resulting from the application pest information can be defined as

$$\pi = p\phi(x, z) - rx - wz$$

where  $p$  is the market price,  $\phi(x, z)$  is the producers production function,  $x$  is a (1 by  $V$ ) vector of pest information,  $z$  is a (1 by  $Z$ ) vector of production inputs other than information,  $r$  is the price vector associated with  $x$ , and  $w$  is the price vector associated with  $z$ . Assuming that output  $\phi$  and product price  $p$  are stochastically independent, the mean of profit is given by

$$E(\pi) = E(p\phi - rx - wz) = E(p)E(\phi) - rx - wz,$$

where  $E$  is the expectations operator. Differentiating  $E(\pi)$  with respect to  $x$  under the assumption of perfect competition in the product and input markets, so that  $p$  is nonstochastic  $E(p) = p$  and  $V(p) = 0$ , yields

$$(1) \quad \partial E(\pi)/\partial x = p\partial E(\phi)/\partial x - r.$$

The  $E(\pi)$  is thus maximized when the value of expected marginal product is equal to the input price.

Variance of  $\pi$  is expressed as

$$V(\pi) = V(p\phi - rx - wz) \\ = [E(p)]^2 V(\phi) + [E(\phi)]^2 V(p) + V(p)V(\phi).$$

Differentiating with respect to  $x$  given perfect competition,  $V(p) = 0$ , results in

$$(2) \quad \partial V(\pi)/\partial x = p^2(\partial V(\phi)/\partial x).$$

Equation (2) states that the addition to the variance of  $\pi$  given an additional unit of the input  $x$  is equal to the output price squared times marginal risk. Price squared ( $p^2$ ) is positive, but the sign of marginal risk is subject to empirical evaluation; however, marginal risk is positive for most inputs (Batra). IPM is a method designed to encourage producers to purchase pest information as insurance against risk at the expense of pesticides. This implies

$$(3) \quad \partial V(\pi)/\partial x = p^2(\partial V(\phi)/\partial x) < 0.$$

Given that the major motivation for pest information and pesticide applications is risk reduction, agricultural producers would generally consider risk in their preference ordering,  $U(\pi)$ . Levy and Markowitz demonstrated that the first two moments of Taylor series approximation closely approximates preference ordering and yields a utility function for  $U[E(\pi)]$  as

$$U = U[E(\pi)] + U_2[E(\pi)]V(\pi)/2.$$

Thus, the utility of a risk prospect  $\pi$  is assumed to be equal to the utility function evaluated at the mean of  $\pi$  plus the products of the second moment of  $\pi$ , the corresponding derivative of the utility function, and the inverse factorial.<sup>3</sup>

The first-order conditions for a maximization of  $U = U[E(\pi), V(\pi)]$ , assuming that the utility function is quadratic or that  $\pi$ 's are normally distributed, yield

$$\partial U/\partial x = [\partial U/\partial E(\pi)] [\partial E(\pi)/\partial x] + [\partial U/\partial V(\pi)] [\partial V(\pi)/\partial x] = 0.^4$$

This implies

$$(4) \quad \partial E(\pi)/\partial x + \{[\partial U/\partial V(\pi)]/[\partial U/\partial E(\pi)]\} \partial V(\pi)/\partial x = 0.$$

The ratio in the brackets measures the rate of utility substitution between  $E(\pi)$  and  $V(\pi)$ . This is the negative of the slope of an iso-utility curve in  $(E, V)$  space or the negative of the risk evaluation differential quotient REDQ (Magnusson).

Substitution of equations (1) and (2) into equation (4), assuming perfect competition and rearranging terms, yields

$$(5) \quad r = p\partial E(\phi)/\partial x - \text{REDQ} [p^2\partial V(\phi)/\partial x].$$

The optimal value of  $x$  occurs when the marginal input cost equals the value of expected marginal product minus REDQ times price squared and marginal risk. The modification for profit maximization under certainty is apparent

<sup>3</sup> Higher moments such as skewness and kurtosis could be included in the utility function. Incorporating these moments yields

$U(\pi) = U[E(\pi)] + U_2[E(\pi)]E[\pi - E(\pi)]^2/2 + U_3[E(\pi)]E[\pi - E(\pi)]^3/6 + \dots$   
Higher moments were excluded from the utility function because the first two moments closely approximate the function and the higher moments do not enrich the conclusions drawn from this paper.

<sup>4</sup> The second-order conditions for the existence of a maximum are very involved and obscure; therefore, they are not presented. An interested reader may refer to Magnusson for a discussion of these conditions. In addition, Anderson, et al. state that since any serious empirical work will probably resort to numerical exploration of conditional expected utility surfaces, the second-order conditions will automatically be taken into account.

in equation (5). A producer will attempt to equate input cost to expected marginal product minus a marginal risk deduction.

Given risk aversion on the part of producers,

$$(6) \quad \partial U/\partial V(\pi) < 0 \text{ and } \partial U/\partial E(\pi) > 0,$$

implies REDQ is greater than zero. In addition, given equation (3),

$$p^2 \partial V(\phi)/\partial x < 0.$$

That is, more pest information will be demanded, given risk aversion, under uncertainty than under certainty.

### POLICY IMPLICATIONS

Pest information is an optional joint-impact good and, as such, nonparticipants are affected by a participant's use of a pest information program. Let  $x'$  be pest information inputs obtained from participants and  $x''$  be pest information obtained from nonparticipants receiving pest information from participants. Thus a participant will equate

$$r = p\partial E(\phi)/\partial x' - \text{REDQ} [p^2\partial V(\phi)/\partial x'].$$

That is, the marginal input cost of pest information is equated to the expected marginal product of information minus the marginal risk deduction. However, the nonparticipant receives the pest information at zero marginal input costs. That is,

$$0 = p\partial E(\phi)/\partial x'' - \text{REDQ} [p^2\partial V(\phi)/\partial x''].$$

Alternative pricing implications result, depending on the degree of jointness of pest infor-

**TABLE 1: Input Effect and Risk Preference Related to Model Implications**

Case	Input Effect	Risk Preference	Nonparticipant Model Implications
1	$\partial E(\phi)/\partial x'' = 0$	no	$r \geq p\partial E(\phi)/\partial x'$
2	$\partial E(\phi)/\partial x'' = 0$	yes	$r \geq p\partial E(\phi)/\partial x' - \text{REDQ}\{p^2\partial V(\phi)/\partial x'\}$
3	$\partial E(\phi)/\partial x'' > 0$	no	$r \geq p\partial E(\phi)/\partial x'$ $0 \leq p\partial E(\phi)/\partial x''$
4	$\partial E(\phi)/\partial x'' > 0$	yes	$r \geq p\partial E(\phi)/\partial x' - \text{REDQ}\{p^2\partial V(\phi)/\partial x'\}$ $0 \leq p\partial E(\phi)/\partial x'' - \text{REDQ}\{p^2\partial V(\phi)/\partial x''\}$

mation and producer risk preference. Table 1 lists four cases of different combinations of cross input effects (jointness) and risk preference.

In the first case, non-jointness and no risk preference are assumed. Thus, a participant will equate marginal input cost to the value of expected marginal product. The nonparticipant will not participate at this level of cost, because the value of expected marginal product is less than the marginal input cost for the nonparticipant. Given non-jointness and no risk preference, there exists no market failure. Optimal institutional policy would then be to promote the marketing of pest information and provide incentives for the reduction in cost of providing pest information.

Case two introduces risk preference, given non-jointness. In this case, the participant employs pest information beyond the point where marginal input cost equals value of expected marginal product because of uncertainty. As Feder noted, part of the uncertainty regarding pest control is a result of genuine random factors, while there is a portion that is perceived by the producer because of insufficient knowledge. These two elements of uncertainty are readily apparent in equation (5). Marginal risk is the portion of uncertainty that is composed of genuine random factors, whereas REDQ is the perceived random variation by producers.

If marginal risk is zero, that is,

$$\partial V(\phi)/\partial x = 0,$$

then optimal policy would be to equate the marginal input cost to value of expected marginal product. Given this marginal risk assumption, producers should then be made aware of the fact that pest information does not decrease variation in yield. Thus, producers should not purchase additional units of pest information as insurance against random variation in yields. Instead, if REDQ is zero and marginal risk is non-zero, then producers have no risk preference and will equate marginal input cost to value of expected marginal product. In this case, if society is interested in decreasing random variation in yields, it would have to encourage implementation of additional management procedures directed toward decreasing variation in yields: for example, provide more incentives for producers to employ pest information that diminishes yield variation. The magnitude of marginal risk deduction depends on the level of REDQ and marginal risk that must be assessed empirically.<sup>5</sup>

In addition, given case two, more producers are likely to participate because of the incentive to insure against risk. If the expected marginal product of participants is equal to the expected marginal product of nonparticipants,

<sup>5</sup> This discussion has assumed that the variance in yield remains constant on the interval of pest information; however, this assumption may not be true in practice. For the implications of this type of heteroscedasticity, refer to Feder.

$$\frac{\partial E(\phi)/\partial x'}{\partial E(\phi)/\partial x'} \Big|_{\text{participants}} =$$

$$\frac{\partial E(\phi)/\partial x'}{\partial E(\phi)/\partial x'} \Big|_{\text{nonparticipants}},$$

then the difference in participation versus non-participation is the net marginal risk deduction between participating and nonparticipating producers. Again, this case does not result in market failure; however, additional pest information is employed here compared to case one because of risk preference. Therefore, the need to reduce pest information cost is not as certain in this case.

A more realistic assumption, case three, is that some degree of jointness exists. That is, the greater the degree of jointness, the more the expected marginal product of  $x''$  deviates from zero. First, assuming again no risk preference, the nonparticipant does not participate because  $r \geq p\partial E(\phi)/\partial x'$ . But the nonparticipant does employ the pest information obtained by the participant at zero marginal cost. Thus, to some degree, market failure is present as a result of the effects of wealth distribution. Participants pay for the information, while nonparticipants receive it at zero cost. Efficiency is obtained when producers are charged for information with the result that marginal input cost equals the value of expected marginal product. Because of market failure, this would suggest a governmental institution's entering the market and providing the information to producers at a fixed cost (Haveman; Demsetz; Baumol). The producers may not agree on the quality and quantity of information that should be provided, or on the level of resources devoted to providing information. To avoid this problem, it has been suggested that a governmental agency charge each producer at a level equivalent to the producer's value of expected marginal product. Producers with differing marginal products of a joint-impact good generally may not prefer being exposed to this type of discriminatory monopolist pricing and therefore would be willing to accept the equity effects of the markets. Samuelson calls this "Robin-Hood" pricing. In addition, a greater loss in welfare may occur through market intervention than the net gain in welfare resulting from such action (Coase; Bator).

The argument for government intervention into market for information is further weakened when risk preference is considered, case four. As

with case two, a producer may still participate if

$$r = \frac{p\partial E(\phi)/\partial x'}{p\partial E(\phi)/\partial x'} \Big|_{\text{participant}} =$$

$$\frac{p\partial E(\phi)/\partial x'}{p\partial E(\phi)/\partial x'} \Big|_{\text{nonparticipant}},$$

because of net marginal risk deduction. In this case the producer may choose not to participate and become a free rider. In the extreme case, this results in

$$(7) \quad r = \frac{p\partial E(\phi)/\partial x'}{p\partial E(\phi)/\partial x'} \Big|_{\text{participant}} =$$

$$\frac{p\partial E(\phi)/\partial x'}{p\partial E(\phi)/\partial x'} \Big|_{\text{nonparticipant}}.$$

Therefore, producers would generally become free riders. However, for some producers, the marginal risk deduction for participation is different from the marginal risk deduction for non-participation, even given equation (7). Thus the net marginal risk deduction in this case distinguishes between those who participate versus those who do not. That is, the reason for participation versus nonparticipation is not only a difference in expected marginal product, but also differences in risk preference. In effect, participants are purchasing additional insurance versus the nonparticipant. Again given risk preference, the requirement for governmental intervention becomes ambiguous.

## SUMMARY AND CONCLUSIONS

Investigation into the characteristics of pest information reveals that it is a joint-impact commodity. Thus for economic efficiency, the possibility of a regulated market exists. Consideration of uncertainty, as well as jointness in a producer's decision with regard to pest information, leads to the following results: as the degree of jointness and marginal risk tend toward zero, generally no market intervention is necessary. As pest information becomes more of a joint-impact good, the problem of equity is encountered, and the justification for government intervention is strengthened. However, increased marginal risk deduction between nonparticipants and participants results in additional complications in stating that a regulated market for pest information is required for efficiency. Thus, further research is required before the conclusion is made that pest information should be provided by a governmental agency.

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