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LEVELS OF PEST CONTROL AND UNCERTAINTY OF BENEFITS

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There seems to be a widespread view that greater uncertainty about private benefits from pest control, for instance because of greater uncertainty about the level of infestation of a pest population, results in greater levels of private pest control. The amount of pesticide (for example, the quantity of a herbicide used for weed control) or effort applied in controlling a pest is often believed to rise as uncertainty about the economic value or effectiveness of the control increases. This matter does not appear to have been explored extensively in the relevant economic literature, although some writers suggest that an effect of this type arises because of risk aversion on the part of landholders (Norgaard 1976; Feder 1979). It is shown here that such an effect can arise even under risk neutrality. Furthermore, general conditions involving convexity of functions that determine whether increased uncertainty about the effectiveness of a pest control measure raises or reduces the optimal value of the relevant pest control variable are specified. In the concluding section some possible policy implications of the results are considered.

Expected Profit Maximisation and the Uncertainty Effect

First, consider the risk neutral case in which a landholder wishes to maximise the expected profit from pest control. In order to evaluate the impact of uncertainty, the expected level of the landholder's pest control variable under complete information (for instance, quantity of herbicide used) can be compared with that under uncertainty, assuming that relevant relative frequency and probability distributions are identical.

Suppose that a state of nature which affects the landholder's benefits from pest control can be measured by a variable θ. This state of nature may refer to the level of the pest population, the ambient conditions influencing the effectiveness of the pesticide or the quality of the pesticide itself. When uncertainty is present, the variable θ is uncertain in value and is uncontrolled by the landholder. Let r represent the application rate (level of use) of the pest control factor. This variable is controlled by the landholder and may, for example, be the quantity of a herbicide applied to control weeds in a particular crop. Assuming given prices for produce and for inputs, the profit function of the landholder is:

$$(1) \quad \pi = f(\theta, r) - C(r)$$

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where the first term on the right hand side represents the gross gains from the pest control measure and the second term represents its cost. If θ is known, the necessary condition for maximising (1) is:

(2) $\partial f/\partial r = C'(r)$

and hence r should be at a level ensuring that marginal gain in revenue from pest control is equal to its marginal cost. The expression $\partial f/\partial r$ will usually depend on θ and, hence, the optimal value of r will normally vary with θ.

Let the optimal value of r as a function of the (known) value of θ be represented by:

(3) $r = h(\theta)$

The expected value of r under complete information therefore is:

(4) $E[r] = E[h(\theta)]$

Under uncertainty, and assuming that $E[\pi]$ is to be maximised, the optimal value of r is:

(5) $r = h(E[\theta])$

if certainty equivalence prevails. Certainty equivalence prevails if the objective function, π, is linear or quadratic in the uncontrolled variable, r (Theil 1961).

Whether or not the value of r in (5) exceeds $E[r]$ in (4), depends on whether $h(\theta)$ is strictly concave or not. Given that all θ values are not equal

(6) $h(E[\theta]) \gtreqless E[h(\theta)]$

accordingly as $h(\theta)$ is strictly convex, linear or strictly concave (Hardy, Littlewood and Polya 1934). An example of a strictly concave h function is one in which the optimal application rate of the herbicide, r, increases with θ but at a decreasing rate, that is, the case in which $h'>0$ and $h''<0$.

The most usual situation may be one in which $h'>0$ and $h''<0$. Such a case would occur, for example, if (2) is of the form:

(7) $g(r) + a\theta = C'(r)$

where $C''>0$ and the second-order conditions are assumed to be satisfied. However, it may also arise in other cases where θ, the random variable, does not enter in a linear manner.

A strictly concave case of $h(\theta)$ is illustrated in Figure 1. Suppose that the values of the relevant environmental variable, θ, are θ_1 with a relative frequency of 0.5 and θ_2 with the same relative frequency. Under complete information, the expected value of r is as indicated in Figure 1 by $E[r]$. Under uncertainty, the expected value of θ is $E[\theta] = 0.5\theta_1 + 0.5\theta_2$. Consequently, if certainty equivalence exists, expected profit is maximised for $r = \hat{r}$. As illustrated, $\hat{r} > E[r]$ because of the strict concavity of $h(\theta)$.

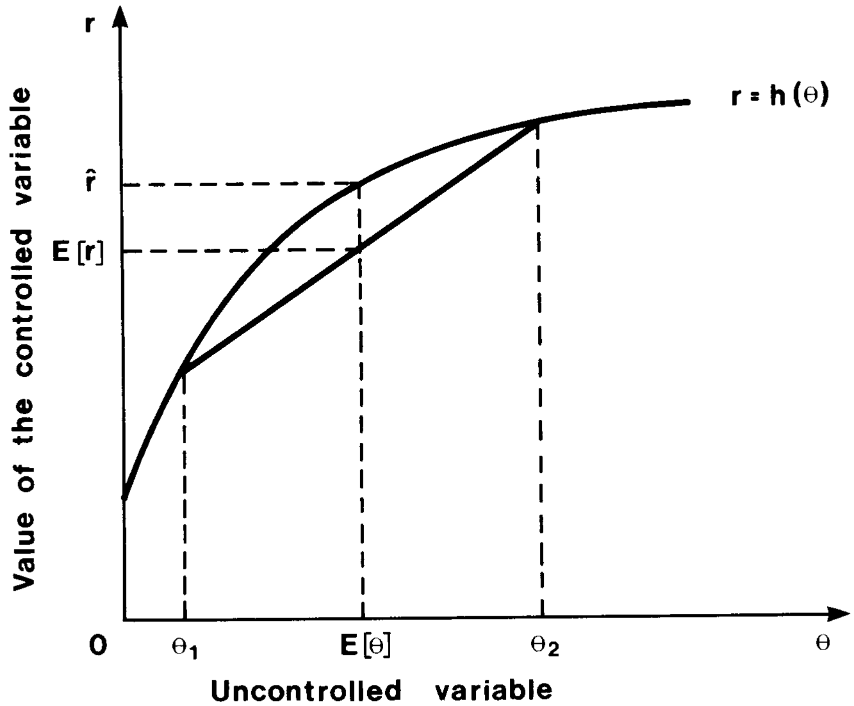

FIGURE 1—A Case where Uncertainty Increases Pest Control 'Effort' in the Absence of Risk Aversion.

The above argument shows that even when a firm's or landholder's objective is to maximise expected profit, uncertainty can cause a rise in the value of a controlled variable, such as the level of pest control, compared with the expected value of the controlled variable under full information. While this may be the most common consequence of uncertainty as far as pest control is concerned, convexity conditions may sometimes be such as to give rise to the opposite consequence.

Generalisation, Qualifications and Other Matters

The analysis is not restricted to the objective of expected profit maximisation. It can be applied to other cases in which the objective is to maximise the expected value of the desired variable. For instance, it can be applied to expected utility maximisation. If the utility function is $U = U(\pi)$ where U represents utility, it may be possible to express the value of r maximising U as a function of θ, that is, in the form $r = h(\theta)$, as considered previously.

Consequently, the previous argument can be applied *mutatis mutandis*. If $h(\theta)$ is strictly concave, for example, and if certainty equivalence occurs, the value of r maximising $E[U]$ exceeds the expected value of r under complete information. The optimal value of the controlled variable as a function of the value of the uncontrolled variable, $r=h(\theta)$, may change the convexity of its relationship as θ alters. For example, the optimal value of r may increase at first at a decreasing rate with θ but once θ exceeds some threshold may become stationary, that is, change from strict concavity to linearity. Such a possibility is implied by the relevant ecological literature (Bullen 1970). Alternatively, the relationship may be S-shaped in some cases and thus alter from strict convexity to strict concavity. This complicates the analysis but can be incorporated.

In some cases, the relationship $r=h(\theta)$ is quadratic, or can be approximated by a quadratic over the relevant domain of the variable, θ. In such cases, the difference between $E[r]$, the expected value of r under complete information, and $\hat{r}$, the optimal value of r under uncertainty, is a linear function of the variance of θ, given that certainty equivalence exists. Where $r=h(\theta)$ is quadratic and c is the coefficient of θ^2, $E[r]$ exceeds $\hat{r}$ by $c[\text{var}(\theta)]$ if c is negative and if c is positive, r exceeds $E[r]$ by $c[\text{var}(\theta)]$. In these cases, var(θ) can be used to measure the degree of uncertainty, when it exists, and the difference between the controlled variable under uncertainty and under full information can be seen to increase linearly with the degree of uncertainty.

The assumption of certainty equivalence is needed for precision of the above results. However, this assumption is not necessary if one merely wishes to compare the optimal application rate r for a stable θ equivalent to $E[\theta]$ with the expected application rate $E[r]$ given a variable value of θ and assuming complete information. The above analysis applies to this case without difficulty. For example, where the actual application rate $r=f(\theta)$ is strictly convex, the value of r, for instance the application rate of a herbicide, can be expected to be lower when θ is stable than the expected value of r when θ is unstable. This is assuming that $E[\theta]$ is the same in both instances and the appropriate knowledge conditions are met.

Note that the analysis has application both in relation to the time dimension and the spatial dimension. Pest control measures often need to be taken before future infestation of the pest or the benefits from control are fully known (Chisaka 1977). This may be the most common situation. However, there are sometimes circumstances where a pest is known to be in part of a general area but one is uncertain about its exact location or it is known that responses to a pest control measure may vary by areas but one cannot identify the precise variation. In these circumstances, the analysis can also be applied. For instance, it implies that if $r=f(\theta)$ is strictly concave, then the application of the pest control per unit of area will be greater if there is uncertainty about θ than if the expected or average level of application per unit of area if full information exists about θ. On the other hand, if $r=f(\theta)$ is strictly convex, the opposite relationship holds.

Information as a Strategic Policy Variable and Conclusions

This note suggests that it may be possible for governments to use provision of information to landholders about pests and their impacts to influence landholders' behaviour, that is, to influence the level of application of pest control adopted by landholders. Depending on the convexity of the relationship between the controlled variable and the non-controlled variable, the provision of information by the government may lead to decreased or increased levels of application of pest control on average. In the strictly concave case, decreases in average rates of application can be expected as the result of the provision of appropriate information. If net unfavourable externalities are associated with the pest control measures, this could strengthen any case for providing such information in the strictly concave case. In the strictly convex case, greater information can be expected to result in higher rates of application by pest controllers and if net favourable externalities are associated with greater levels of application of pest control, this could help to provide an argument in favour of the public provision of information. Externalities associated with pest control may, however, be positive or negative depending on the circumstances (Langham and Edwards 1969; Hueth and Regev 1974; Feder and Regev 1975; Taylor and Headley 1975; Tisdell 1982*a*, *b*).

In conclusion, uncertainty of non-controlled variables can have a material impact on the optimal value of controlled variables, including the level of application of inputs intended to control pests. In many cases, the expected level of application is greater under uncertainty than under full information but, as explained in this note, this depends on convexity conditions of relevant functions. These results are not dependent on the maximisation of expected utility and risk aversion as invoked in an earlier explanatory model presented by Feder (1979). In general, many of the consequences of uncertainty for the nature of economic behaviour are not dependent on these hypotheses (Hart 1942).

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