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Assessing the Approach to Cost-Benefit Analysis of Controlling Livestock Diseases of McInerney and Others

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ABSTRACT

Outlines the basic cost-benefit analysis of Mcinerney of the optimal control of livestock diseases and presents it in a different and more readily understood form. Furthermore, this analysis is extended to discussions about the control of several diseases, for example, how to allocate available funds between the control of several diseases if net benefits are to be maximized. McInerney assumes that there is diminishing marginal net benefit from increased expenditure on the control of any livestock disease. However, this is too restrictive. It is possible that marginal net benefit at first increases and then decreases with increased expenditure on the control of some livestock diseases, and other possibilities also cannot be ruled out. The consequences of relaxing McInerney's assumption about the nature of this net benefit curve are considered. Although it is true that indiscriminate use of benefit-cost ratios about the economics of control of livestock diseases, can lead to misleading policy advice as McInerney has claimed, they play a useful role in determining whether it is economical to control a livestock disease at all and in allocating priorities to the control of different livestock diseases. Priority should be given to controlling those diseases that are capable of yielding the highest benefit-cost ratios but it does not follow that the benefit-cost ratio of any disease targeted for control should be maximized.

Keywords: Animal disease, McInerney.

JEL Codes: Q160

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1. Introduction

Economic analysis of the optimal control of animal diseases can be complex because of the diversity of diseases, considerable differences in their epidemiology and nature of occurrence as well as variations in possible treatments and responses. In addition to taking such biological factors into account, economic analysis must take account of relevant prices and costs. Therefore, combined effort by economists and non-economists, such as veterinary scientists, is needed to apply economic analysis to the control of animal diseases.

Because the world is complex, simplified models are needed to help us understand it and in effect, they are often idealised samples of the world. These models frequently involve reductionism - they hold several factors constant and abstract from the real world. This is true for the cost-ben fit analysis of the control of livestock diseases proposed by McInerney and others (McInerney, 1991; McInerney, Howe and Schepers, 1992).

One of the aims of McInerney's approach is to point out the dangers involved in using benefit-cost ratios to make decisions about the optimal control of animal diseases. This method has been applied, for example, to the optimal economic control of mastitis (McInerney et al., 1992). The purpose of this paper is to examine the analysis, extend it and to point out modifications that may be needed for its application.

2. The Basic Model/Analysis

McInerney's (1991) model is extremely simple. Animal diseases cause losses in economic benefits or profits but by spending on the control of a disease its occurrence or severity can be reduced and so some of the loss which would otherwise have occurred can be avoided. The loss avoidance function suggested by McInerney is of the following form

$$L = A - f(E) \qquad (1)$$

which is assumed to decrease at a decreasing rate. L represents the loss avoided, A the loss if there is no expenditure on the control of the disease under consideration and E represents the level of expenditure on the control of the disease.

Rather than represent the function in the way that McInerney does, it is somewhat easier to use if it is expressed as

$$B = f(E) \qquad (2)$$

when B represents the benefit (loss avoided) as a result of expenditure on controlling a disease. When $E = O$; the total loss incurred is A because $f(E) = o$ for $E = o$. If this function is of a similar form to McInerney's loss avoidance function, it increases at decreasing rate ($f' > o$, $f'' < o$) and will have an upper limit of A. Thus the total benefit function would be of the form shown in Figure 1 by curve ODFG. It may or it may not reach the limit A. If it reaches the limit A, expenditure is sufficient to prevent the occurrence of the disease. Total cost can be represented by a 45° line from 0 shown in this case by the line OH. Consequently, the level of expenditure which minimizes such benefit is E_1.
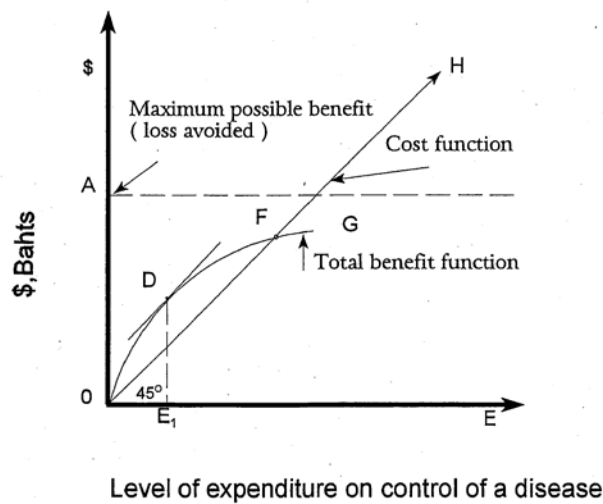
Figure 1   A different presentation of McInerney's model

If only one disease is under consideration, net benefits (N) are maximized when

$$N = B - C \qquad (3)$$

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is at a maximum. The necessary condition for this is that marginal benefits be equal to marginal costs which in this case requires that

$$f'(E) = 1 \qquad\qquad (4)$$

This means that expenditure on health control should continue up until it returns the last dollar spent.

Given the general situation depicted in Figure 1, benefit per dollar spent on animal health control of a particular disease might be represented by a curve like JKM in Figure 2 and the marginal benefit (the additional benefit obtained by spending an additional dollar on controlling the disease) might be represented by the curve marked JPQ. Curve JPQ is below JKM and both decline given McInerney's approach. In this case, it is apparent that the benefit-cost ratio rises as expenditure on health control declines. This is so because curve JKM declines as E increases. Thus, as suggested by McInerney, if one aimed to maximize the benefit-cost ratio this would result in a very low level of expenditure on disease control in this case and would not maximize net benefits. These are maximized for a level of expenditure of E_1.
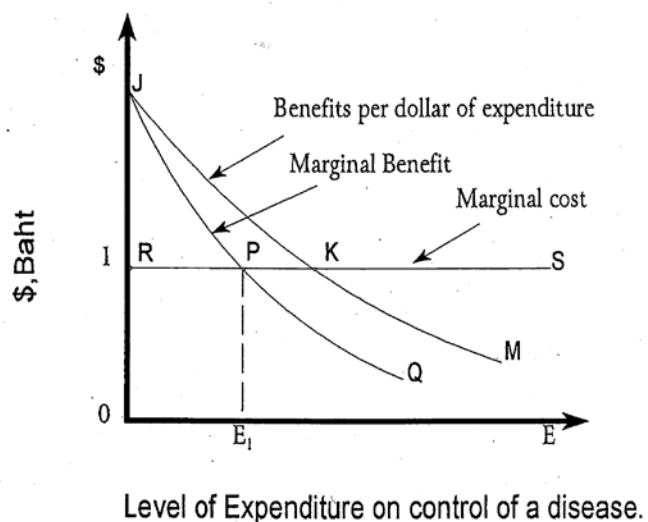
Figure 2   Per unit benefit and cost curves derived from Figure 1

The benefit function obtained from McInerney's approach is like an economic production

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function because it assumes that the greatest possible benefit is obtained for any level of expenditure incurred in controlling the disease. This is because McInerney's loss avoidance function supposes that maximum reduction in loss is obtained for any given level of expenditure on control of a disease. This implies that the benefit function is an efficiency frontier.

The above is of course quite a major assumption because it implies that technical/veterinary knowledge is used to maximum advantage in controlling the disease relative to the cost constraints and that the economic costs of resources used to control the disease are optimally taken into account.

3. Extending the Analysis to the Optimal Control of More Than One Disease

Generally farmers or graziers have to make decisions about controlling more than one disease so let us consider how McInerney's analysis might be extended to cover this situation. If there are $i = 1... n$ diseases to consider, then the simplest extension of this analysis is as below if there is no interdependence between diseases and the cost of their control. The problem becomes one of maximizing total benefit, T and this occurs when

$$T = \sum_{i=1}^{n} N_i = \sum (B_i - C_i)$$

(5)

is at a maximum.

Given the same form of the relationship for all diseases as for the single one considered above, this requires that

$$\sum N_i = \sum (f_i(E_i) - E_i)$$

(6)

be maximized. The necessary condition for this is that

$$f_i'(E_i) = 1 \text{ for } i = 1, \ ...n,$$ (7)

that is that expenditure on the control of each disease be expanded until the net benefit

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obtained from controlling each is equal to the last dollar spent on the control of each. Given that $f_i' < o$ everywhere, the second order condition for a maximum is automatically satisfied.

However, for some diseases it may not be worthwhile spending anything on their control – a corner-point solution exists. This occurs when the benefit per dollar spent on control of a disease is less than unity for every level of expenditure. In such a case, the benefit per dollar curve shown in Figure 2 is everywhere below the per unit cost curve. Thus for every disease that it is economical to control, condition (7) should be satisfied.

The above however supposes that there are no constraints on available funds for controlling animal diseases. In practice, this is often not the case. The availability of funds from savings or from financial markets may be such that there are insufficient funds to meet the above optimality condition. When this is so, all funds should be distributed between diseases so that the marginal benefit from spending on the control of each is equalized. At the optimum, because of the funding constraint, the marginal benefit will exceed unity (one dollar) for diseases which it is worthwhile controlling.

A further complication which has to be considered for some diseases is interdependence. For example, treatment for one disease or pest may reduce the likelihood of occurrence of other diseases or pests. For instance, some treatments for cattle tick in Australia reduce the incidence of buffalo fly. Secondly, treatment for one disease may reduce the cost of treating another. For example, if the first requires mustering of cattle, it may then be relatively easy to take preventative measures in the second while the cattle are mustered. In such cases both benefits and costs for control of different diseases can be interdependent and total net benefit needs to be expressed in the general form

$$T = T(E_1, E_2, \ldots E_n) \tag{8}$$

The necessary condition for a maximum of this is

$$\frac{\partial T}{\partial E_1} = \frac{\partial T}{\partial E_2} = \cdots = \frac{\partial T}{\partial E_n} = o \tag{9}$$

It can be shown that for any given level of expenditure on total disease control, that the optimal balance or distribution in expenditure between diseases is achieved when the marginal contribution of each to total net benefits is equal.

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The situation is readily illustrated for circumstances involving two diseases. In this case, the total benefit function is

$$T = T (E_1, E_2) \qquad (10)$$

The problem is that for any given total expenditure on disease control total net benefits be maximized.

Assume that k is a given level of expenditure on health control. Then

$$k = T (E_1, E_2) \qquad (11)$$

represents the corresponding health control possibility curve in terms of net benefits.

It may be for example represented by curve ABC in Figure 3. Total net benefit (when unconstrained) can be expressed as

$$T = T_1 + T_2 \qquad (12)$$

which clearly is a. simple linear relationship. For any given level of net benefit, say Π_1,

$$\Pi_1 = T_1 + T_2 \qquad (13)$$

and therefore

$$T_2 = \Pi_1 - T_1 \qquad (14)$$

If for example, Π_1, corresponds to OM in Figure 3, the corresponding iso-net benefit line is as indicated by MBL which has a slope of −1. This is one of an (infinite) number of such iso-net profit lines (some others are indicated in Figure 3 by dashes) which are parallel and correspond to increasing net benefits as one moves in a north-easterly direction. Hence, given the level of expenditure k, it follows that the allocation of expenditure on disease control corresponding to point B is optimal. This is because it is on the highest attainable iso-net benefit line.
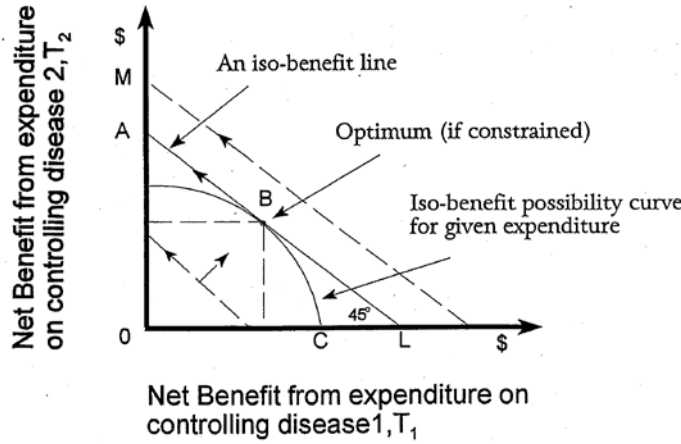
Figure 3   Constrained economic optimisation of disease control for more than one disease

In the case illustrated in Figure 3 the optimal balance of expenditure on control of the two diseases corresponds to point B. At this point, the rate at which the net benefit from controlling disease 2 has to be foregone to increase the rate of net benefit from controlling disease 1, equals the latter. The tangency point at B implies that

$$\frac{\partial T}{\partial E_2} / \frac{\partial T}{\partial E_2} = -1 \tag{15}$$

until rearranging implies that

$$\frac{\partial T}{\partial E_2} = \frac{\partial T}{\partial E_1} \tag{16}$$

Adapting standard microeconomic theory, the model can be further extended to bring in the concept of an expansion or efficiency path. This shows the combinations of disease control that maximize net benefits for each level of total expenditure on control or those which minimize total costs of disease control for any level of net benefits aimed for.

For different levels of total expenditure or disease control, different iso-net benefit curves can be expected to be generated with those further to the northeast corresponding to higher levels of expenditure. So in Figure 4, curve DEF represents iso-net profit for a higher level of expenditure on disease control than k. Relative to this expenditure, E may be the optimal allocation of the expenditure between diseases. Allowing expenditure to vary, all points of

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optimality may generate a curve like OBEH which is the expansion or efficiency path. Maximization of net benefits requires that operations be such as to be on this path. In theory, and in the absence of expenditure constraints, the farmer should proceed along this path until his/her marginal net benefits are zero. This may occur say at point G.

Figure 4   Introducing the concepts of an expansion or efficiency path and of duality

From the above, a duality can be seen to be present: if net benefit is to be maximized:

1. It is necessary for maximum net benefit to be obtained from whatever expenditure on disease control is undertaken.

2. It is also necessary for net expenditure on disease control to be at a minimum for whatever net benefit is obtained.

These two sides of the coin can be quite useful from a management point of view because sometimes expenditure on disease control is limited to a total amount and on other occasions the target is to undertake sufficient expenditure to obtain a particular level of net benefit from disease control.

4. Modifying McInerney's Basic Model

The above extends McInerney's basic model to cover several diseases. However, the basic

model requires some modification to take better account of the economics of controlling some animal diseases. For example, the basic model assumes that diminishing marginal benefit occurs everywhere, as one increases expenditure on the control of a disease. However, it is conceivable that for some disease control programmes increasing marginal benefits at low levels of expenditure occur but eventually give way to diminishing marginal benefit. Initially, the total benefit curve is strictly convex and then becomes strictly concave.

Furthermore it is possible that no benefit is obtained in some cases unless control expenditure exceeds some threshold value. For example, there may be minimum start-up or establishment costs for a disease control program. Without the required minimum expenditure, no control of the disease is obtained.

Figure 5 illustrates a case where the marginal benefits from disease control expenditure increase at first and eventually decline. In this case the associated curves for benefit per unit of expenditure on disease control are of an inverted U-shape of the form shown in Figure 6. In Figure 5, the curve OABCD represents the benefits from expenditure on controlling the disease and the line OF represents its costs. Unless expenditure falls in the range $E_1 < E < E3$, no net benefit is obtained from expenditure on controlling the disease. E_1 is a break-even point and may be regarded as a threshold. In this particular case, maximum net benefit occurs for $E = E_2$. In Figure 6 the curve OHJK is per unit benefit, $f(E)/E$, corresponding to benefit curve OABCD and curve ORST represents marginal benefit, $f'(E)$. Line UV represents the marginal and average cost of spending on disease control. It is unity.
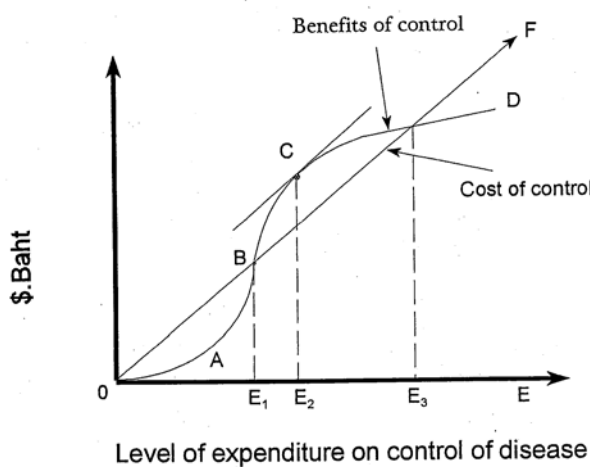

Figure 5 Relaxing McInerney's example of strict concavity of the benefit function from controlling of disease
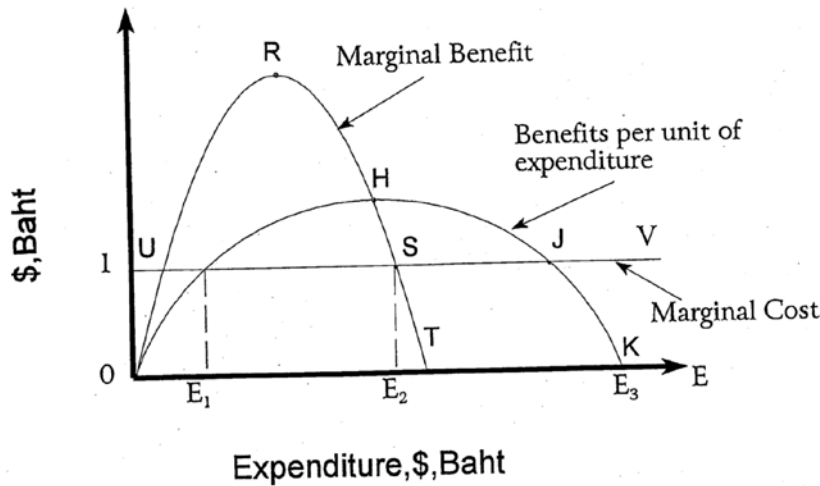
Figure 6   Per unit curves corresponding to the total curves shown in Figure 5

The second case mentioned above is illustrated by Figures 7 and 8. The same type of function is assumed as used by McInerney but no benefits is obtained until $E > E_1$. Benefit equals zero for $E \leq E_1$ and equals f (E) for $E \geq E_1$ where f' > o and f'' < o. The benefit curve in Figure 7 is represented by curve OABCD. No benefit is received until a threshold of expenditure of E_1 is achieved. No net gain from treating the disease is obtained until a threshold expenditure of E_2 occurs. The optimal expenditure is E_3. The corresponding per unit curves will be of the nature shown in Figure 8. Marginal benefit is at first zero and average benefit for low levels of expenditure is negative. Note that in this situation two types of threshold exist.
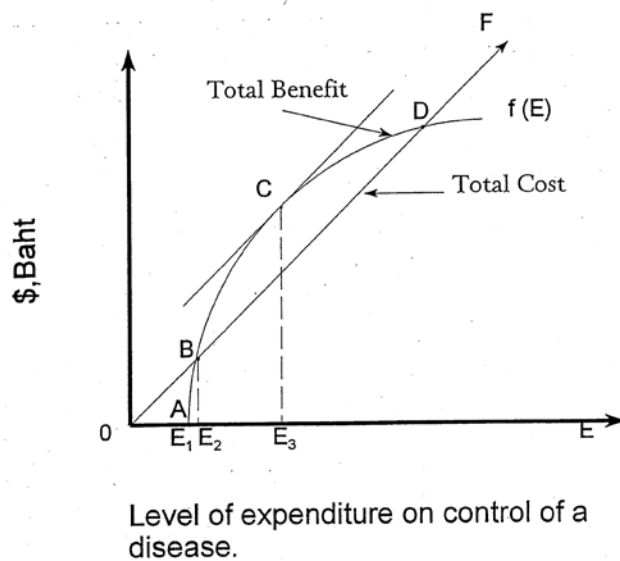

Level of expenditure on control of a disease.

Figure 7   A case in which no benefit is received from spending on disease control unless expenditure reaches a threshold level.
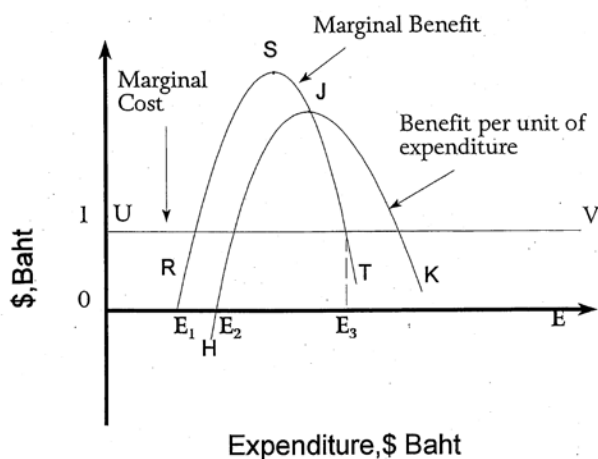
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Figure 8   Type of marginal curves corresponding to curves shown in Figure 7

Note that if there is going to be a net benefit from treating any disease, the per unit benefit curve must exceed the per unit cost curve for some level of expenditure on the disease. This implies that the benefit-cost .ratio must exceed unity for some level of expenditure on the control of the disease. Diagrammatically line UV must intersect the per unit cost benefit curve that is, curves HJK in Figures 6 and 8.

When the benefits from the control of multiple diseases are independent, expenditure on control should only occur for, diseases for which benefits can exceed costs. If funds for control of diseases are in short supply, priority should be given to controlling •those diseases for which the benefit-cost ratio is highest assuming that expenditure is optimally allocated between the diseases being treated. It is in this case that benefit-cost ratios are important. These ratios are important for optimising even though it would be incorrect to use these to determine the optimal scale of spending on any disease which is to be controlled; the point made by McInerney (1991).

5. Benefit-cost Ratios Important for Determining Optimal Disease Control Expenditure

The above indicates that benefit-cost ratios are very important for determining the optimal control of diseases, despite McInerney's appropriate caution about their inadequacy for determining the optimal scale of control of a particular disease. Indeed, from an economics point of view, diseases can be prioritised for control using these ratios. The following rule can be adopted assuming the control of each disease is independent: compute the maximum

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benefit-cost ratio for each disease. Highest priority for control should be given and those diseases with the highest benefit-cost ratios or the highest net benefit per unit of expenditure. The latter, for example, would correspond to the maximum of a curve like OHJK shown in Figure 6.

Having calculated such ratios, diseases should only be controlled for which the benefit-cost ratio exceeds unity. For all diseases controlled, the level of expenditure on their control should equate marginal net benefits from controlling each. If funds are in short supply, this rule should still be applied for all diseases controlled but only those with the highest benefit-cost ratios are worthwhile controlling.

Control of each disease can be looked upon as a project. So cost-benefit analysis developed for decisions about investment projects can be adapted to deciding on which diseases to control and the level of control to exert on each (Tisdell, 1972, Ch.21).

While benefit-cost ratios are unsuitable as a rule to determine the economically optimal level of control of a disease, in some cases maximizing average returns (which are in fact indicated by benefit-cost ratios) can sometimes provide an adequate approximation for determining an optimum, as pointed out in Tisdell, 1993, Ch.7.

6. Concluding Comments

While the basic model proposed by McInerney for the cost-benefit analysis of the control of livestock diseases is interesting, it is a special case. As discussed it can be extended in a number of ways e.g. to the control of several diseases, or to allow for the possibility that the marginal net benefits from expenditure on disease control are not everywhere declining. Further extensions also seem desirable to allow for the presence of uncertainty and the role of information gathering in the optimal control of livestock diseases. McInerney's analysis assumes unbounded rationality, that is, complete information and unimpeded optimising behaviour. These assumptions are not likely to be satisfied in practice. In addition, McInerney's criticism of the use of benefit-cost ratios for determining the optimal economic control of livestock diseases while justified in the context in which he discusses it, is not justified in the context of economic decisions about the control of different livestock diseases. The ratios are important for assigning economic priorities to the control of different livestock diseases.

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