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Working Paper No. 4

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The Commissioned Organization is the Queensland Department of Primary Industries. Collaborating institutions in Australia are CSIRO-ANHL, Geelong, Victoria and the University of Queensland (Department of Economics; Department of Geographical Sciences and Planning). In Thailand, the collaborating institutions are the Department of Livestock Development (National Institute of Animal Health; Disease Control Division), Chiang Mai University (Department of Agricultural Economics; Department of Animal Husbandry) and Thammasat University (Faculty of Economics). The collaborating institution in Laos is the Department of Livestock and Veterinary Services. Dr F.C. Baldock, Senior Principal Epidemiologist, Queensland Department of Primary Industries is the Project Leader in Australia and Dr P. Chamnanpood, Senior Epidemiologist, Thai Department of Livestock Development is the Project Leader in Thailand. Professor Clem Tisdell and Dr Steve Harrison, Department of Economics, University of Queensland are responsible mainly for the economic component of this project.

'The overall goal of this project is to develop and evaluate the .necessary tools to provide decision-makers with reliable animal health information which is placed in context and analysed appropriately in both Thailand and Australia. This goal will be achieved by improving laboratory diagnostic procedures; undertaking research to obtain cost-effective population referenced data; integrating data sets using modern information management technology, namely a Geographical Information System (GIS); and providing a framework for the economic evaluation of the impact of animal diseases and their control.

A number of important diseases will be targeted in the project to test the systems being developed. In Thailand, the focus will be on smallholder livestock systems. In Australia, research will be directed at the northern beef industry as animal health information for this sector of livestock production is presently scarce.'

For more information on *Research Papers and Reports Animal Health Economics* write to Professor Clem Tisdell (c.tisdell@economics.uq.edu.au) or Dr Steve Harrison,(s.harrison@uq.edu.au) Department of Economics, University of Queensland, Brisbane, Australia, 4072.

The Economics of Vaccinating or Dosing Cattle Against Disease: A Simple Linear Cost-Benefit Model with Modifications

ABSTRACT

Outlines a simple linear cost-benefit model for determining whether it is economic at the farm-level to vaccinate or dose a batch of livestock against a disease. This model assumes that total benefits and costs are proportional to the number of animals vaccinated. This model is then modified to allow for the possibility of programmes of vaccination or disease prevention involving start-up costs which increase, but at a decreasing rate with batch size or with the size of the herd to be vaccinated. In this case, vaccination is more likely to be profitable the larger is the herd or the batch size. Consequences of uncertainty for economic decisions about vaccination are considered. The minimax gain criterion, minimax regret criterion and expected gain criterion are applied to vaccination choices under uncertainty. Other things equal, risk-aversion or uncertainty avoidance increases the likelihood of farmers vaccinating their animals. Attention is brought to the need for research on the economics of improving estimates of the likely occurrence of livestock diseases.

Keywords: Animal disease, livestock vaccination, herd size.

JEL Code: Q160

The Economics of Vaccinating or Dosing Cattle against Disease: A Simple Linear Cost-Benefit Model with Modifications

1. Introduction

In the case of livestock, many measures for the prevention of diseases require treatment of individual animals. This is for example true of vaccination programmes. In consequence, even though there may be some set-up costs for any disease prevention programme, variable costs as a fraction of the number of animals treated is likely to be a significant component of total cost. A simple linear model is introduced in this paper to take account of this and then extended. Although actual relationships may not be linear (see Mcinerney, 1991; Mcinerney et al., 1992; Tisdell, 1995), linearity sometimes provides a useful approximation to non-linear relationships. Furthermore it is sometimes more economical to approximate non-linear relationships by linear ones than to try more sophisticated approximations given that greater sophistication is likely to involve greater cost in information gathering and extension.

2. The Simplest Linear Model

Consider the net economic benefits to a farmer of vaccinating or dosing animals against a particular disease. Let

- x represent the number of animals vaccinated,
- b represent the benefit per animal successfully vaccinated,
- c represent the cost per animal vaccinated,
- p represent the proportion of vaccinated animals for which vaccination is successful,
- r represent the proportion of animals expected to get the disease in the absence of vaccination, and
- L represent the economic loss that occurs per animal when the disease occurs.

It follows that the expected net benefit from vaccinating *x* members of a herd is

$$V = p\,b\,x - c\,x, \qquad (1)$$

at is expected gain less the cost of vaccination.

Because the expected benefit of treating x beasts, is the expected loss avoided, namely *r L* per beast treated, expression (1), net benefit, may be rewritten as

$$V = p\,(r\,L)\,x - c\,x \qquad (2)$$

that is expected loss avoided less the cost of vaccination (Cf. Tisdell, 1995).

Consequently, it pays to vaccinate a herd of size *x* if

$$p\,b > c \qquad (3)$$

or if $$p\,(r\,L) > c, \qquad (4)$$

that is, if the benefit per beast vaccinated exceeds the cost of its vaccination. If the inequality is removed, no prevention is optimal.

Given that the whole herd is homogeneous from the point of view of disease control, it will either pay to vaccinate the whole herd or not to vaccinate it at all. The simple case is illustrated in Figure 1 in which it pays to treat the whole herd of size x_1 Line OB represents the expected benefit from vaccination and line OC the cost of vaccination.

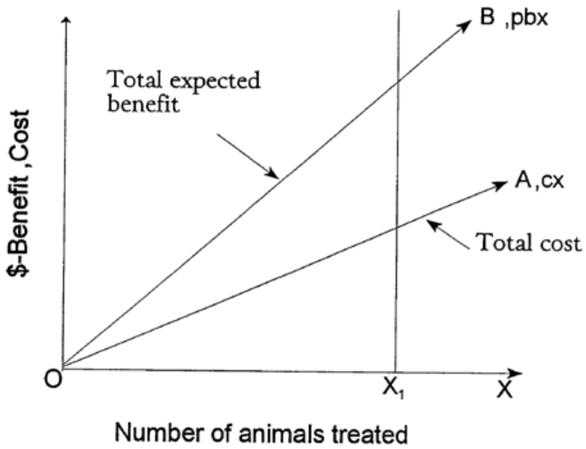

Figure 1 A case in which it pays to vaccinate all animals in a herd

In order to make the model operational, it is necessary to estimate the coefficients *p, r, L* and *c*. Coefficients *p* and *r* basically have a natural scientific basis whereas the other two coefficients depend on economic factors.

While the above assumes homogeneity in benefits from control, often the benefits of preventing a disease will vary between different classes of animals. For example, if Akabane virus infects animals which are not pregnant it causes virtually no clinical effects or production and economic loss (Radostits, Blood & Gay 1994). If however, Akabane virus infects pregnant cows, it can result in severe losses due to the birth of weak and deformed calves. Therefore it may be only worthwhile vaccinating animals in a particular class, in the case of Akabane virus, females which are to be bred.

In another case, that of the tick transmitted *Babesia bovis*, young animals, less than 9 months old, can become infected with the disease causing organism and become immune but do not show any signs of disease. Older animals are much more severely affected by this disease resulting in considerable production loss (Callow 1984). If farmers are selling animals before they reach 9 months old it may not be worthwhile vaccinating the animals which are to be sold.

Therefore, this simple model may be applied to groupings to determine the profitability of vaccinating. Groupings might be by age, sex or other relevant characteristics of animals.

3. Some Modifications to the Basic Model

The above model assumes that there is no required start-up cost for a control programme. But the costs of vaccinating might in practice consist of two components – start-up costs plus cost per animal vaccinated. Start-up costs include the cost of mustering and in the longer-term the costs of holding yards and crushes for animals. Although the total variable costs of vaccinating animals may be linear, the start-up costs of vaccinating a herd of animals may increase with herd size but at a decreasing rate. Thus the total vaccination cost function may be of the form

$$C = h(x) + a\,x \qquad (5)$$

when $h' > o$, and $h'' > o$. The first component and the right hand side of equation (5) represents start-up costs and the second component represents total variable costs. This means that the cost of vaccinating a herd increases with herd size but at a decreasing rate. If $h(x) > o$ for $x > o$, that is if any level of vaccination requires positive start-up costs, herd size must be sufficiently large for vaccination to be economic. Hence, herds of larger size may be vaccinated but not smaller ones. In the case illustrated in Figure 2, the herd size must exceed x_1 before vaccination becomes profitable. Line OBD represents total benefits and line CBE indicates total costs.

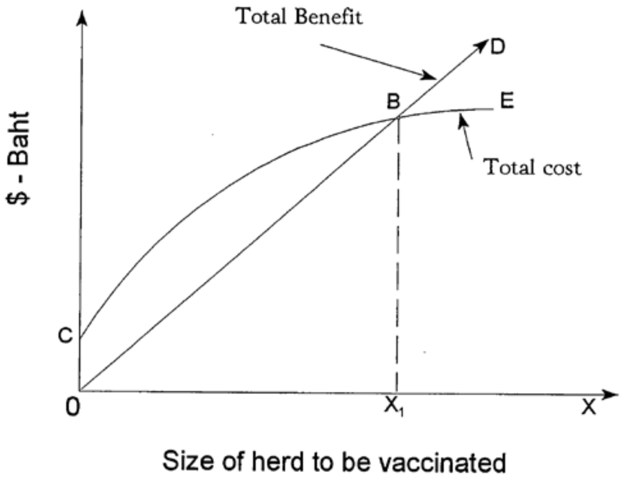

Figure 2 Profitability of vaccinating a herd depends on its size

In countries where the sizes of herds owned by individuals are very small, the cost of vaccinating cattle (or buffalo) can be reduced by the provision of communal yards and crushes. In Thailand for example, such facilities exist in many villages and co-ordinated village vaccination tends to be common.

The above model(s) abstract from uncertainty about the extent of loss avoided by vaccination. For most infectious diseases there will be uncertainty about the likely level of exposure of the herd to a disease in the absence of vaccination and about the level of the net benefit to be obtained from preventing an animal from being infected. When uncertainty is taken into account, farmers who are risk-averse are more likely to vaccinate their cattle. Simple illustrations based on game theory can be used to support this proposition.

Suppose that there are two possible degrees of incidence of disease in a herd: a low rate of infection, s_1, and a high rate, s_2, and that two alternative strategies are available, namely, a_1, vaccinate the whole herd each a_2, do not vaccinate at all.

The profit or net benefit available to the grazier might then be like that shown by the matrix in Table 1. It depends upon whether the incidence of the disease in a herd is high or low in the absence of vaccination and on whether vaccination of the herd takes place.

Table 1 Net benefits of vaccinating or of not doing so for a high and a low risk of a livestock disease

		Low rate s_1	High rate s_2	
Vaccinate	a_1	80	100	80*
Do not Vaccinate	a_2	90	60	60

In the case illustrated in Table 1, a livestock owner who wanted to maximise his/her security would vaccinate because this maximises his/her minimum possible net benefits. This strategy corresponds to the maximum value for the minimum of the rows of the matrix in Table 1 and assures the farmer of a net benefit of at least 80 units. This strategy is sometimes called the minimax security strategy. Furthermore, this strategy would be adopted if the farmer happened to be a 'satisficer' and considered an income level greater than 60, for example 70, to be satisfactory.

An alternative possibility is that the farmer wishes to minimise his maximum regret or possible opportunity cost in deciding whether or not to vaccinate against a disease. To determine the optimal strategy from this point of view, we can form a regret matrix using Table 1. This is shown in Table 2. From Table 2 it can be seen that the minimax regret strategy is to vaccinate against the disease.

Table 2 A regret matrix obtained from Table 1

	s_1	s_2	
a_1	10	0	10*
a_2	0	40	40

If the farmer aims to maximise the expected net benefit, this would imply no risk-aversion. For the example shown in Table 1, if p indicates the probability of a low incidence of the disease, then expected benefit from vaccinating is $p\ 80 + (1 - p)\ 100$ and from net vaccinating, it is $p\ 90 + (1 – p)\ 60$. When these two values are equal, expected benefits from the alternative strategies are equal. Let this occur for p_1 In this case, this occurs for $p = 0.8$.

Hence, vaccination will maximise expected profit if $p < 0.8$, or if the likelihood of a high level of infection in the absence of vaccination exceeds *0.2*.

This situation can be illustrated by Figure 3 when the probability of a low rate of disease is shown on the X-axis and the expected payoff from the alternative strategies are measured on the Y-axis. Given the possibilities indicated in Table 1, line AB represents the expected payoff if no vaccination of the herd occurs and line CD indicates expected payoff if vaccination takes place. One can see that vaccination maximises expected gains if $p < 0.8$ which implies that $(1 - p) > 0.2$, that is the probability of a high rate of disease exceeds 0.2. Incidentally, if one is completely uncertain about whether a high or low rate of disease is likely to occur, then by the principle of insufficient reason this would lead to a probability of *0.5* being assigned to a low rate of disease and to the same being assigned to a high rate of disease. Hence vaccinating of the whole herd would be optimal on an expected net gain basis.

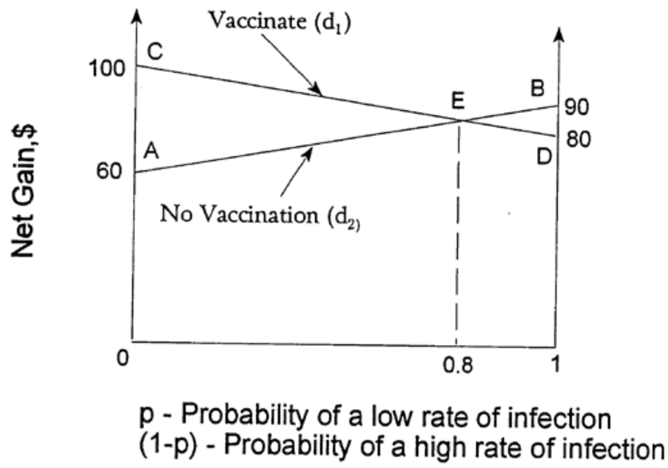

Figure 3 Diagram to determine whether there is a net expected gain from vaccination

The above example can be generalised using linear algebra. Furthermore, other criteria are possible. For example, criteria based on a combination of expected gain and risk-avoidance considerations. However, if risk avoidance is a part of the farmer's aim, then the likelihood that vaccination is optimal increases with the probability of the occurrence of the disease.

A major problem, however, is how to predict the possibility of occurrence of the disease in the absence of vaccination and the likely level of disease. Serological testing of livestock has been suggested as a possible means of improving such predictions. The economic value of improved predictions will depend to some extent on the type of decision criterion used by the farmer. If for example, the farmer is using a minimax security strategy then increased information about the probability of level of disease would not change his/her decision, provided the range of possible levels of disease remained unchanged. On the other hand, this would not be• the case if the farmer aims to maximise expected gain.

4. Concluding Comment

Information about the likely occurrence of diseases in particular herds and the economics of vaccinating against such diseases is normally limited. Perfect decision-making about disease control in the field in particular herds is rarely if ever attainable. However, simple linear (or near linear) models may be used to improve economic decisions about disease control because these require relatively little information for estimation. While still likely to result in imperfect decisions, these decisions may be a significant improvement on those involving little or no economic structuring of disease control problems.

It should be noted that this paper does not take account of the external benefits of vaccinating a herd (Tisdell et al., 1994) because it concentrates on the decision of the individual farmer. Also, no allowance is made for the possibility that vaccination will not only decrease the amount of disease that occurs in vaccinated animals but will also reduce the risk of disease occurring at all due to rising herd immunity (Cf. Tisdell, 1995).

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