2

Economic decision making in animal health management

A.A. Dijkhuizen[1], R.B.M. Huirne[1] & R.S. Morris[2]

1) Department of Farm Management, Wageningen Agricultural University, Wageningen, the Netherlands

2) Department of Veterinary Clinical Sciences, Massey University, Palmerston North, New Zealand

Objectives

From this chapter the reader should gain knowledge of:

- basic principles underlying economically sound decision making
- major components of a conceptual model for economic analysis
- production function principles
- cost functions

2.1 Introduction

Economics is sometimes qualified as the discipline that simply measures things in monetary units, while everyone else uses physical units. This view, however, is far too simple and inappropriate. Economics - as a science - primarily deals with **decision making**, whereby money is only one of the elements. **Animal health economics**, therefore, can be described as the discipline that aims to provide a framework of concepts, procedures and data to support the decision-making process in optimizing animal health management (Dijkhuizen, 1992).
Controlling the cost of production is becoming critically important in modern livestock farming. Improving animal health and fertility can play a major role in achieving efficient and economically rewarding production. Current veterinary services are evolving to meet the need for service targeted tightly to the needs of farmers through planned disease prevention and control programs and management for optimum health. The application of these services is rarely an all-or-nothing affair. Usually several programs or measures are available, each of them offering a different degree of protection and requiring a different level of investment. Determining the optimum input level, therefore, is to a large extent a matter of economic decision making. Not only is this the case for the individual livestock owner, but also for a national government that must determine an optimum policy on specific contagious diseases. In this chapter the basic economic framework and principles to rely on when dealing with these aspects are discussed and illustrated.

2.2 The basic economic model

The basic conceptual model underlying economic analyses includes three major components: people, products and resources. It is **people** who want things and make decisions, therefore being the driving force for economic activity. **Products** are goods and services that satisfy people's needs and may be regarded as the outcome of economic activity. **Resources** are the physical factors and services that are the bases for generating the products, and, as such, are the starting points of economic activity. These three components can be put together to portray the basic conceptual model that underlies economic analysis (Figure 2.1).

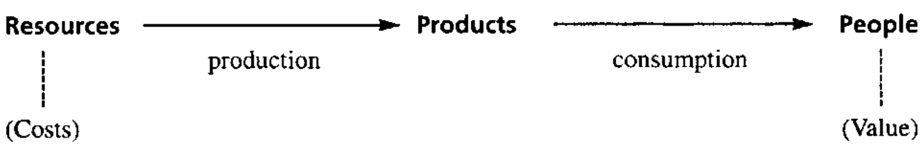

Figure 2.1 The basic model underlying economic analysis (Howe & McInerney, 1987)

In Figure 2.2 animal disease is portrayed in the system as an influence which affects the livestock resource transformation process and results in extra resource use and/or fewer animal products than before (**direct effects**). These direct losses may be immediately visible (death, abortion), or obscured (reduced milk yield). Animal disease may also affect other parts of the economic system, thus diminishing benefits to people (**indirect effects**). These indirect losses can be divided into those that are fairly obvious (collapse of export trade), and those that are obscure (constraints on agricultural developments).
Probably the most useful addition to this basic economic model for certain decision situations would be to include a loop indicating that some animal 'products' are not used for human consumption but as breeding stock, and so form part again of the resource base. In doing this the notion of 'capital' is introduced.

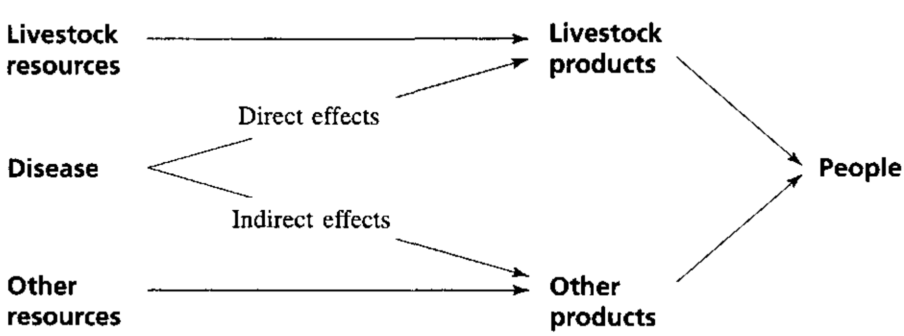

Figure 2.2 Livestock production in the wider economic system

To express the physical effects in economic terms, the 'value' of products and 'cost' of resources are required. The idea of value is not intrinsic in any product or service, but is determined by the people's request for the products, and is relative to their availability ('supply and demand'). Economics attempts to deal with the real value of any product, which may or may not be accurately captured in its recorded price. Similarly, the idea of cost stems from the resources that are used in making a product available. This underlies the definition of the real cost (or **'opportunity cost'**). The opportunity cost of using a resource in a particular way is the value of that resource if it were used in the best alternative way, which again may not adequately be reflected by financial expenditures incurred in its production. Both 'real value' and 'real cost' - and hence the losses from one and the same disease - may differ considerably across the various economic levels to be considered, ie, the individual farmer, the joint livestock owners, the consumers and the national economy, as is illustrated in Table 2.1.

In the case of the **common diseases** that the individual farmer can control (eg, mastitis), supply and demand force animal product market prices to change over time with the average disease level. Thus the resulting losses are transferred to the consumers, and conversely it is the consumer who benefits from improved animal health. On a sufficiently large market (such as the European Union) there is hardly any relation between the extent and severity of these diseases on the one hand, and the average income of the joint livestock owners on the other. However, for the individual farmer this linkage does exist. The farm in question may suffer more (or less) from disease than is compensated for by the average 'disease margin' included in the market price. To a lesser extent this also applies to a group of livestock owners.

In the case of an epidemic of **contagious diseases** (eg, foot-and-mouth disease), market prices of output primarily depend on whether or not restrictions on foreign trade will be im posed. When an outbreak does not lead to export bans, the market prices may temporarily rise a little, depending on the spread and duration of the outbreak. If exports are restricted, however, prices in countries that export much will drop substantially due to an oversupply on the domestic market. This fall in price causes losses which may greatly exceed the direct losses from the disease owing to, for instance, mortality. Unaffected farms also suffer from this drop in market prices. Consumers will benefit, however, making the losses to the national economy considerably fewer than those to the joint livestock owners.

2.3 Veterinary services as an economic input factor

2.3.1 Production function principles

The calculation of the economic losses is not only important for a description of the actual situation, but also for how, and more specifically, to what extent it can help to answer questions such as: (1) how to limit the losses as much as possible if diseases do occur, and (2) in what way and to what extent can the risk of disease be diminished, how much loss can be avoided and what efforts and costs are involved? To base the answers on sound economic criteria, insight into the relationship between the input and output of disease control (ie, veterinary services) is essential. Here, production function and cost analysis play a central role.

The technical relationship between the amount of input(s) and the output produced is

Table 2.1 Losses due to animal disease at various economic levels

Economic level	Type of disease A Disease generally present, but varying in degree per farm	B Outbreaks of contagious diseases on a national or regional scale B1 Foreign trade restrictions	B2 No foreign trade restrictions
1. Farm (individual producer)	Direct relation between loss and degree of the disease per farm. Particularly in pig and poultry farming great effect on income.	Great incidental loss, even if the farm is not affected by the disease. Possible compensation for destroyed animals.	Great loss to the affected farms (possible compensation for destroyed animals); advantage to farms not affected.
2. Sector (joint livestock farmers)	Loss, if the price does not adjust itself. On a sufficiently large market (eg. the EU) hardly any relation between level of disease and income of livestock farmers, due to price adjustment.	Significant loss, particularly in the case of export products, resulting from dropping prices owing to failing demand.	Moderate loss (depending on possible compensations and on degree of price adjustments).
3. Supply and processing industries; service and trade[a]			
4. Consumer	Loss owing to higher prices.	Incidental advantage.	Slight loss.
5. National economy	Loss owing to inefficient use of resources.	Disadvantage considerably less than loss to joint farmers (2B1).	Disadvantage can be more than to joint farmers (2B2), but less than 5B1.

[a] Possible effects have not been specified. Price changes are assumed to be passed on to the consumer fast and completely.

referred to as the factor-product relationship or the production function (Boehlje & Eidman, 1984). It is also commonly referred to as the input-output relationship or response curve. The relationship relates to the amount of products that can be produced for alternative combinations of inputs within a specified time interval, for example one year. If X_i represents the amount of the i^{th} input (eg, veterinary services) and Y represents the amount of products produced (eg, kg of weight gain), then the production function can be written as:

$$Y = f(X_1 | X_2,...,X_n)$$

This relationship indicates that the amount of product Y is a function of the amount of variable input X_1 and the level of the fixed inputs X_2 through X_n.

The relationship between the amount of a single variable input and the output of a single product can take one of three general forms: constant productivity, diminishing productivity and increasing productivity of the variable input. **Constant productivity** exists when each additional unit of variable input added to the fixed factor(s) increases output by the same amount. With **diminishing productivity** each additional unit adds less to total output than the previous one, whereas with **increasing productivity** the opposite occurs. The most classical production function is assumed to include both **increasing and diminishing productivity**, as is illustrated in Figure 2.3.

Total physical product (TPP_{X1}) grows at an increasing rate until output level *a* is reached, and increases at a decreasing rate between *a* and *c*. Beyond output level *c*, total physical product declines with increased input of X_1.

Two other technical relationships - the marginal physical product (MPP_{X1}) and the average physical product (APP_{X1}) - can be derived from the production function and are important in selecting the optimum amount of a variable input. **Marginal physical product** is the increment to total physical product attributable to the addition of a single unit of input ($MPP_{X1} = \Delta TPP_{X1}/\Delta X_1 = \Delta Y/\Delta X_1$) and is, therefore, equal to the slope of the TPP curve at any level of input. **Average physical product** is equal to the average output per unit of variable input and is calculated as total physical product divided by the amount of variable input used ($APP_{X1} = TTP_{X1}/X_1 = Y/X_1$).

From these relationships, three stages of production can be defined, as is also shown in Figure 2.3. Stage 1 is defined as the area in which marginal physical product is larger than average physical product. In Stage 1 the MPP_{X1} curve increases, reaches its maximum (when output gets to level a), and then declines. Average physical product increases throughout the stage and reaches a maximum at the boundary between Stages 1 and 2 (when output gets to level b). Notice that at this boundary marginal physical product and average physical product are equal. Within Stage 2 marginal physical product is further declining, and reaches zero at the boundary between Stages 2 and 3 (when output gets to level c).

Average physical product is declining and positive throughout Stage 2. Stage 3 is characterized by declining total physical product and negative (and declining) marginal physical product. Average physical product, of course, continues to decline in Stage 3.

The three stages provide the decision maker with useful information in defining the range

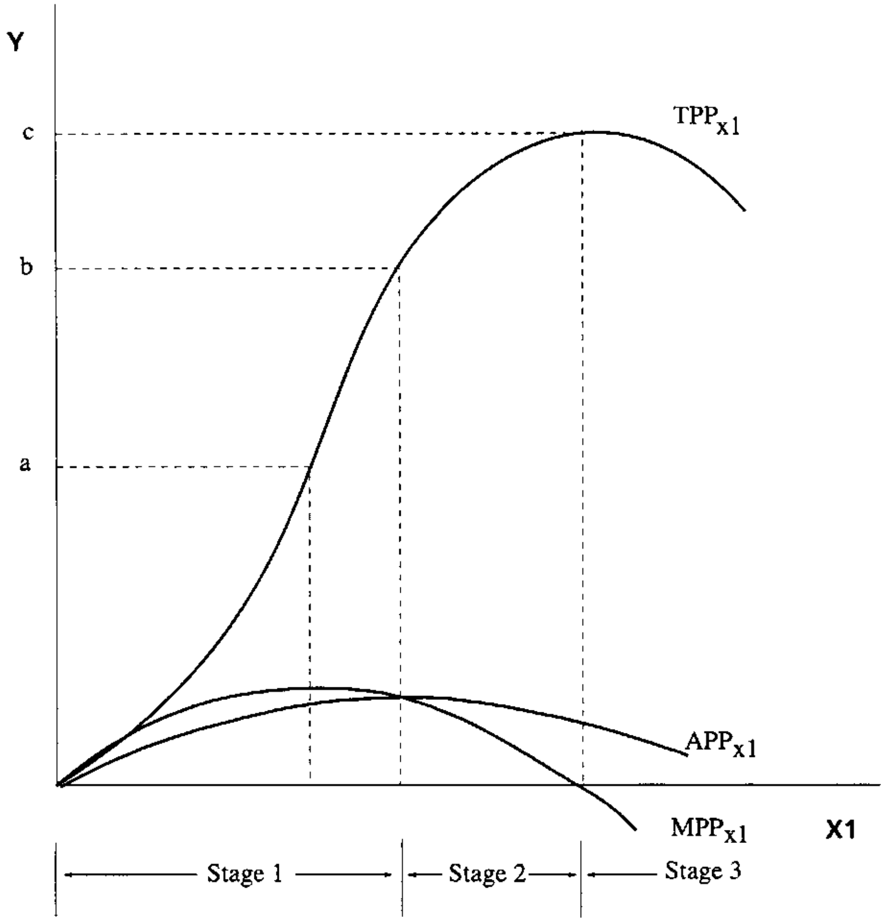

Figure 2.3 The classical production function

which is the most efficient for production. It would be irrational to operate in either Stage 1 or Stage 3 regardless of the level of input and product prices. It is obvious that one would not want to operate within Stage 3. Applying additional units of the variable input and forcing production into Stage 3 reduce the amount of total product produced. If the prices of the variable input and the product are assumed to be constant and positive, one would make more money by leaving some of the variable input unused. Producing within Stage 1 is not rational either, because a more efficient use of the variable input can be obtained by higher levels of input until the APP_{X1} curve reaches its maximum. Production, therefore, should always occur in Stage 2, but the decision maker must consider the prices of input and output in order to determine exactly the profit-maximizing level of the variable input to be used.

To better illustrate the three technical relationships discussed before, a hypothetical response to anthelmintic dosing in growing cattle is summarized in Table 2.2

In Table 2.2 the average physical product curve reaches its maximum with five doses, indicating the boundary between Stages 1 and 2. This boundary is further confirmed by the fact that the marginal product curve intersects with the average product curve. The marginal physical product curve falls below zero beyond six doses, being the boundary between Stages 2 and 3. The rational range, therefore, is narrow in this case and includes five and six doses only (Stage 2).

Table 2.2 Hypothetical response to anthelmintic dosing in growing cattle

Number of doses	Total physical product (kg of weight gain)	Average physical product (kg per dose)	Marginal physical product (Δ kg / Δ dose)
0	0	0	
1	10	10	10
2	30	15	20
3	60	20	30
4	100	25	40
5	130	26	30
6	150	25	20
7	140	20	-10
8	120	15	-20

2.3.2 Cost functions and economic choice

Cost functions are closely related to production functions. They take into account an additional step and include the cost of the various inputs in the input-output relationship. The total cost curves related to the classical production function of Figure 2.3 are shown in Figure 2.4.

As shown in Figure 2.4, cost curves are depicted with the cost on the vertical axis and the amount of output on the horizontal one (notice that the latter was on the vertical axis with the production function in Figure 2.3). The relationships for **total variable cost** (TVC), **total fixed cost** (TFC) and **total cost** (TC) are given by the following equations (with P_{xi} being the input prices):

$$TVC = P_{x1}X_1$$

$$TFC = \sum_{i=2}^{n} P_{xi}X_i$$

$$TC = TVC + TFC = \sum_{i=1}^{n} P_{xi}X_i$$

Notice the corresponding relationship between the production function (Figure 2.3) and the total variable cost curve (Figure 2.4). Output in Figure 2.3 grows at an increasing rate until output level *a* is reached. The total variable cost curve in Figure 2.4 increases at a decreasing rate within the same range of output. Within Stage 2 (output level *b* to output

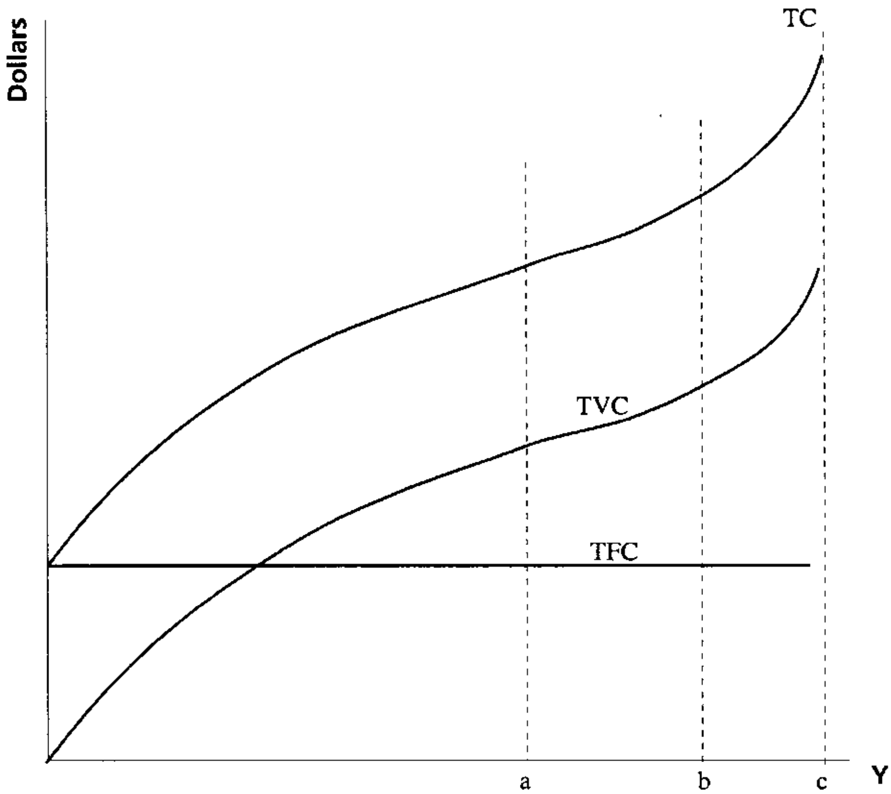

Figure 2.4 Total cost functions (identifying 3 stages of production)

level *c*), total output is increasing at a decreasing rate and total variable costs are rising at an increasing rate. The total cost curves become vertical at output *c*, the boundary between Stages 2 and 3. The vertical curve reflects the fact that cost continues to increase while the addition to output is zero. Total variable costs and total costs would continue to increase as the output level declined, resulting in total cost and total variable cost curves to bend back to the left as they increase. The shape reflects the irrationality of producing in Stage 3. Higher cost levels would be incurred for production of an amount of output equal to that in Stage 2.

The average and marginal cost curves for the classical production function are shown in Figure 2.5. The relationships for the **average fixed cost** (AFC), **average variable cost** (AVC), **average total cost** (ATC) and **marginal cost** (MC) are given by the following equations (with P_{Xi} being the input prices):

$$AFC = TFC / Y$$
$$AVC = TVC / Y = P_{X1}X_1 / Y = P_{X1} / APP_{X1}$$
$$ATC = AFC + AVC$$
$$MC = \Delta TC / \Delta Y = P_{X1}\Delta X_1 / \Delta Y = P_{X1} / MPP_{X1}$$

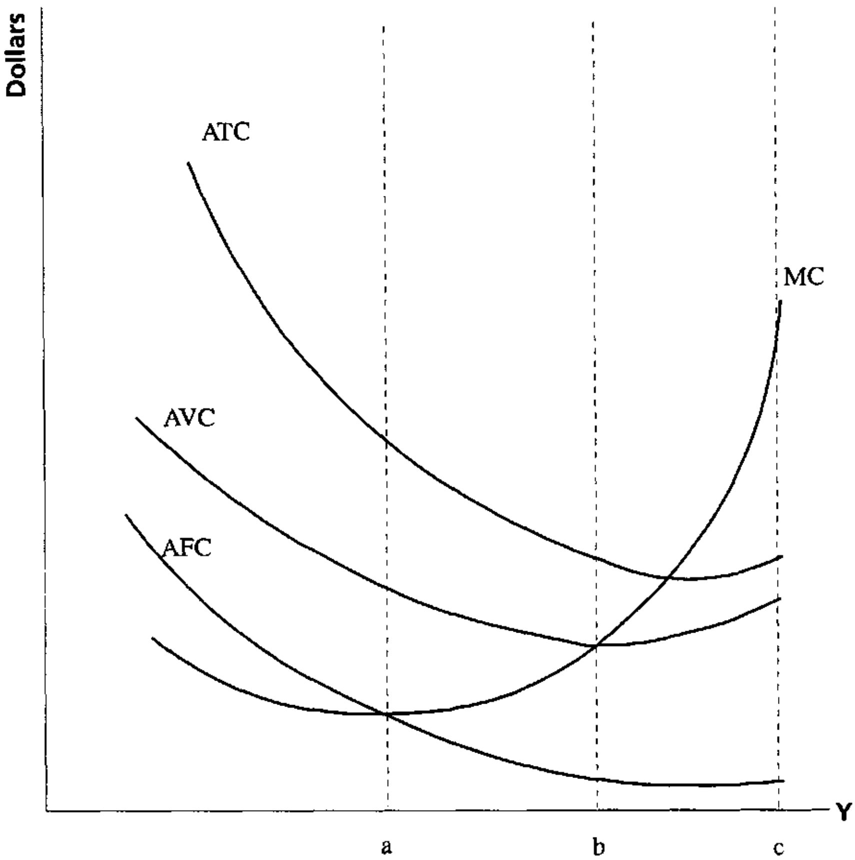

Figure 2.5 Average and marginal cost functions

The minimum average variable cost occurs, as could be expected, at the output level having the maximum average physical product, the boundary between Stages 1 and 2 (indicated by output level *b*). Marginal cost is at a minimum where the MPP_{X1} is maximum - output level *a* in Stage 1 of production. Marginal cost increases when MPP_{X1} declines. It is equal to average variable cost at the boundary between Stages 1 and 2, where $APP_{X1} = MPP_{X1}$. Within Stage 2 net returns will be increased (or losses reduced) by using higher levels of the variable input as long as the marginal cost is lower than the output price ($MC<P_y$). The simple logic is that each additional unit of output produced adds more to gross returns than to cost when $MC<P_y$. **Profit, therefore, is maximized where marginal cost and returns are equal** (in Stage 2).

It is of interest to notice that various cost-minimizing rules are unlikely to lead to profitable output levels. For example, a rule to minimize average variable cost would result in selecting the input level *b* at the boundary between Stages 1 and 2. If P_y is greater than MC at this level, profit can be increased by operating at a higher output level. In the event P_y is less than the minimum AVC, losses will be minimized (ie, reduced to TFC) by ceasing production.

That will make the **supply curve** for a farm identical to the marginal cost curve for all values of prices that exceed average variable cost.
The cost calculations are illustrated in Table 2.3 using the data from Table 2.2 on the hypothetical response to anthelmintic dosing in growing cattle. Fixed costs per head are assumed to be US$100, and input price US$10 per dose.

Table 2.3 Production cost derived from the production function on the hypothetical response to anthelmintic dosing in growing cattle

X1 doses	Y kg	TFC $/head	TVC $/head	TC $/head	AFC $/kg	AVC $/kg	ATC $/kg	MC $/kg
0	0	100	0	100	—	—	—	
1	10	100	10	110	10.00	1.00	11.00	1.00
2	30	100	20	120	3.33	0.67	4.00	0.50
3	60	100	30	130	1.67	0.50	2.17	0.33
4	100	100	40	140	1.00	0.40	1.40	0.25
5	130	100	50	150	0.77	0.38	1.15	0.33
6	150	100	60	160	0.67	0.40	1.07	0.50
7	140	100	70	170	0.71	0.50	1.21	—
8	120	100	80	180	0.83	0.67	1.50	—

The values in Table 2.3 are calculated using the equations presented before. Average variable costs (AVC) are minimal with five doses (US$0.38/kg). The output price P_y (ie, the so-called marginal return), therefore, should not be less than US$0.38/kg, otherwise losses will be minimized (ie, reduced to TFC) by ceasing production. A higher price will make six doses the optimum. More than six doses are not an option because of the negative marginal results. These findings are in agreement with Table 2.2, where five and six doses were found to form the rational range (ie, Stage 2).

Exercise

You can practise the principles of a production function, as discussed in this chapter, with the spreadsheet example in Chapter 19: the farm advisory case. The effects of veterinary services on the number of piglets weaned on a sow farm are shown in a production function. You have to calculate the different cost functions and to find the economically optimal amount of veterinary input. Sensitivity analyses are done to show the effect of changing prices. This exercise takes about 45 minutes. A smaller example with real experimental data on anthelminthics in ewes can give you an indication of how this theory is used in research: you have to find the optimal treatment for this disease. This extra exercise takes about 30 minutes.

2.3.3 Further applications

In considering the production and cost function approach, it was assumed that only one control measure (ie, input) was varied, and all other aspects were held constant. However, in reality various different control measures are usually available and it is not just a matter of deciding with what intensity each individual control measure will be applied, when the intensity of the other ones is held constant. It is necessary to face the question of deciding the optimum combination of two or more measures as well.

The optimum combination of two inputs can again be found by using the marginal principle - the optimum point is where the reduction in cost by eliminating one unit of input A (eg, teat dipping in mastitis control) equals the cost of the additional amount of input B (eg, dry-period therapy in mastitis control) to keep the output (eg, milk production) constant. Just as an optimum combination of two inputs can be found, it is possible to calculate the best combination of a larger number of inputs in a similar way. The concept is simple, and formally named the **equimarginal principle**:

> The returns from a scarce or limited resource are maximized when the input is allocated to its most profitable uses in such a way that the returns from the last unit of resource is not only equal or higher than the costs of the last unit of resource, but also the same in each of the alternative uses.

In this way funds will be spread among uses according to their marginal returns (which will of course decline progressively as more funds are invested in a single item). This principle is easy to understand and to use; and is a very powerful economic tool. Yet all too often decisions in animal health management (and elsewhere) are not made in accordance with this principle, either because the information does not exist or because farmers and advisers do not know of it. It is a challenge for both veterinarians and animal health economists to make proper estimates of marginal cost and returns from disease control measures. Once these estimates are available, calculations can easily be redone with other input values to help determine the impact of uncertain estimates on the outcome of the decisions (a so-called **sensitivity analysis**).

There is a wide range of techniques available to help perform these analyses for two or more measures and for more realistic and complicated situations. Both basic methods (ie, partial budgeting, cost-benefit analysis, decision-tree analysis) and advanced techniques (ie, linear programming, dynamic programming, Markov chain simulation, Monte Carlo simulation) are discussed and illustrated in the following chapters.

References

Boehlje, M.D. & Eidman, V.R., 1984. Farm management. John Wiley & Sons, New York, 806 pp.

Dijkhuizen, A.A., 1992. Modelling animal health economics. Inaugural speech, Wageningen Agricultural University, Wageningen, 28 pp.

Howe, K.S. & McInerney, J.P. (eds), 1987. Disease in livestock: economics and policy. EUR 11285 EN, Commission of the European Communities, Brussels, 190 pp.