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Cost-effectiveness analysis: adding value to assessment of animal health, welfare and production

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Summary

Cost-effectiveness analysis (CEA) has been extensively used in economic assessments in fields related to animal health, namely in human health where it provides a decision-making framework for choices about the allocation of healthcare resources. Conversely, in animal health, cost-benefit analysis has been the preferred tool for economic analysis. In this paper, the use of CEA in related areas and the role of this technique in assessments of animal health, welfare and production are reviewed. Cost-effectiveness analysis can add further value to these assessments, particularly in programmes targeting animal welfare or animal diseases with an impact on human health, where outcomes are best valued in natural effects rather than in monetary units. Importantly, CEA can be performed during programme implementation stages to assess alternative courses of action in real time.

Keywords

Animal health and welfare – Cost-benefit analysis – Cost-effectiveness analysis – Economic assessment.

Introduction

There is increasing awareness of the need to underpin decisions on resource allocation for animal health, welfare and production measures with structured and transparent frameworks (1, 2). Through comparative analysis of alternative courses of action in terms of cost and consequences, economic analysis provides such a decision-making framework and helps to guide decision-makers in integrating evidence in the allocation of scarce resources (1, 3, 4).

Various economic evaluation tools based on a range of economic theories are available according to the objective of the analysis. Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) are the most commonly used.

Cost-benefit analysis uses monetary units to quantify costs and outcomes and has a broader scope of application than other types of analysis, providing information on the allocation of resources across different sectors of the economy. Nevertheless, well-known problems associated with CBA, particularly the difficulty of measuring health, biological and environmental effects in monetary units and the ethical concerns surrounding this exercise, have dictated a limited use of CBA in human health and other areas (3, 5, 6).

Cost-effectiveness analysis overcomes this problem of attributing monetary figures to some effects, by calculating, within a fixed budget, the incremental costs in units of currency while expressing benefits in the most appropriate natural non-monetary effects. Unlike CBA, CEA requires an external standard such as a budget constraint or threshold to assess the value of the programme. In addition, by using non-monetary effects to express the benefits, CEA is programme specific and can only compare interventions that use the same units of effectiveness (1, 4, 7).

In the analysis of animal health, welfare or production interventions, CBA has been the preferred tool for economic evaluation to date (8) and is used either to justify a defined strategy (ex-ante analysis) or to assess the impact of a past programme (ex-post analysis) (9). However, during the implementation stage, CBA has shown limitations for assessing the effectiveness of resource use (10). In fact, economic tools and skills are rarely used during this phase of animal health programmes, meaning that economics is not contributing and adding value to the largest element of animal health projects.

Significant lessons can be learned from a literature review of how CEA has been applied in related fields, namely in human health. This paper reviews the fundamentals of CEA and its application in related areas and addresses its present use and the potential added value in animal health, production and welfare interventions.

General framework of cost-effectiveness analysis

In a CEA, a series of steps should be undertaken to reach a cost-effectiveness ratio that allows comparison of decision options (Fig. 1).

Identification of the problem and establishment of the conceptual model

Identification of the problem, the intervention and its alternatives are the first steps of the analysis. The conceptual model, outlining the full range of events arising from the intervention, is frequently shown using a decision tree (5).

Establishment of the analytic perspective

The analysis can be undertaken from a number of perspectives, as the people involved may have differing views on the most advantageous policy (4). Usually CEA takes either the societal or the programme perspective, with costs and benefits of the interventions valued differently (5, 7). Whereas in the programme perspective only outcomes and costs experienced by the entity of interest are taken into consideration (7, 11), in the societal perspective all significant outcomes and costs are determined independently of who pays or benefits from the effects (7).

Identification and estimation of costs

Total direct costs compose the numerator of the cost-effectiveness ratio and include all goods, services and other resources that are consumed in provision of an intervention or in dealing with its side effects and the present and future consequences associated with the intervention (7).

In human health, methodological guidelines clearly establish the categories of cost that should be considered in the calculation of total direct costs. The direct costs of the intervention, such as tests, drugs, personnel, rent and costs of patients' time, should be included. In addition, costs associated with caregivers' time and direct non-health care costs should be considered (4, 5, 7).

Micro-costing techniques, where the correct monetary value of every input used is enumerated, provide an option for valuation of costs but can be time consuming and therefore uneconomic. As a result, gross costing, where estimates of costs are obtained, is more frequently used (5).

Because cost-effectiveness results are sensitive to the time horizon of the analysis, it is important to cover the entire period of time on which the intervention has an effect (4), and both costs and benefits when spread over time should be discounted and take inflation into consideration (5).

Identification and estimation of outcomes

Effectiveness estimations constitute the denominator of the cost-effectiveness ratio (7) and a vast range of measures of effectiveness can be used, reflecting the diversity of effects (4).

In human health, common outcomes that are used are changes in life expectancy and/or improvement of quality of life, such as quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs) (12). These can be measured across various interventions and allow comparison.

To evaluate effectiveness, data might be sourced from randomised control trials or observational studies. As in the estimation of monetary benefits for an animal health CBA, collecting primary data can consume both time and resources. Outcome data are most frequently derived using mathematical modelling, meta-analysis and Bayesian methods (4).

Estimation of cost effectiveness and sensitivity analysis

The results of a CEA are normally presented in the form of a ratio that expresses the price per effectiveness unit. Cost-effectiveness ratios can be reported in two forms. As an average ratio, where

$$\textit{CE ratio} = \frac{\text{cost of the intervention}}{\text{effectiveness of the intervention}}$$

or as an incremental cost-effectiveness ratio, where programme alternatives are compared:

$$\textit{CE ratio} = \frac{\text{cost intervention} - \text{cost alternative}}{\text{effectiveness intervention} - \text{effectiveness alternative}}.$$

Incremental cost-effectiveness ratios (13) are generally presented in the analysis of mutually exclusive programmes, as a direct comparison of the alternatives, but do not allow examination of whether current practice is efficient (3). Importantly, incremental comparisons should be made with the next-best option to avoid distortions in the calculations (4, 14). Sensitivity analysis should assess the effect on the conclusion of the various assumptions made in the analysis (4).

Use of cost-effectiveness analysis in related areas

A review of the medical literature published between 1990 and 2000 by Hutubessy *et al*. revealed that an average of 497 papers on CEA were published each year and also showed that, in the sphere of human health, CEA studies were more common than CBA studies (3). Decisions on the allocation of healthcare resources and prioritisation of interventions for both private and public healthcare systems (13) and at the patient level have been informed using CEA.

In addition to the field of human health, CEA has been applied in many other disciplines, such as energy, transport, ecology and the environment, where valuation of outcomes in terms of natural effects has a methodological advantage (15, 16, 17).

Methodologies of CEA are not fully harmonised within and across these disciplines. In human health, the harmonisation of methodologies to enhance comparability of studies has been promoted by national and international organisations (7, 18, 19), although methodological variations continue to occur (13).

Current role of cost-effectiveness analysis in assessment of animal health, welfare and production

In human health the use of CEA as a basis for decision-making shows an exponential trend (3), but the technique is not as widely used in veterinary medicine, where CBA and cost analysis have been more common (8, 20, 21, 22, 23, 24, 25), as it is possible to place a value on the majority of mortality and morbidity impacts in animal disease.

Studies on the use of CEA in the field of animal health intervention have generally analysed programmes focusing on the control of zoonotic diseases but have also assessed the cost-effectiveness of diagnostic tests and measures for the prevention of disease introduction. Most reports used ex-ante analysis to compare alternative strategies to achieve an effect. Outcomes of interest vary widely from life years gained to reduction in risk and increased sensitivity of a diagnostic test. Table I summarises the main features of some of these studies.

An example of a recent application of CEA for assessment of animal health, welfare and production is given by Lyons *et al.* (46). The authors evaluated the cost-effectiveness of a series of interventions for control of verotoxin-producing *Escherichia coli* (VTEC) in dairy farms in the United Kingdom. The epidemiological information and selection of interventions assessed in the study were determined in a previous randomised control trial. The authors then developed cost models for the interventions, considering the measures individually and in combination. The outputs (effects) considered were measures of the effect of the interventions in the randomised control trial in terms of risk ratio, which was then converted to the attributable fraction in order to estimate the proportional reduction in the prevalence if the intervention measures were implemented. Subsequently, the cost-effectiveness ratio was calculated as the intervention cost per dairy cow divided by the attributable fraction (46). Unlike a CBA, in this CEA the effect chosen by the authors focused on a technical parameter outcome with an impact on the economic profitability of the farm, but the benefits were not monetised.

Discussion

A well-conducted CEA provides quality information to inform the setting and prioritisation of policy (4, 47). As in human health, it is likely that CEA will become increasingly predominant in assessments of animal health, production and welfare, emphasising the importance of understanding the strengths and limitations of this tool.

The limitations of CEA have been discussed in the context of its widespread use in human medicine. Although CEA aids decision-making, it is not sufficient in itself for making complex decisions on resource allocation, as it does not incorporate aspects of overall budgetary impact, feasibility and societal values such as equity and fairness (4, 48).

Further, the economic foundations of CEA are a matter of much discussion; for example, on controversial methodological aspects such as the inclusion of indirect and productivity costs and discounting of health effects (26). The absence of a clear common acceptable threshold dividing an acceptable from a non-acceptable cost-effectiveness ratio is also considered a constraint. In human health, where attempts to quantify the affordability of a certain threshold have been developed, this is strongly linked to the prosperity of the country, making it difficult to define a common threshold (4, 13).

Other controversial aspects of the analysis relate to ethical concerns arising from the valuation of natural effects, including health. Discounting benefits, for example, implies that an effect observed in the present is more valuable than if observed in the future (27).

Nevertheless, CEA presents various advantages that have contributed to its widespread use in many areas. It is a user-friendly economic tool, as it uses effectiveness measures that reflect the interests of people involved in the process and that can be estimated and used for real-time decision-making.

In assessments of animal health, welfare and production, CBA can be used for ex-ante and ex-post evaluations where costs and benefits can be estimated in a monetary valuation, such as programmes dealing with livestock diseases and production. When benefits include welfare changes for humans and/or animals that are complex to measure in monetary terms, CEA is an alternative tool that could capture more appropriately the desired outcomes from a change. These typically include programmes that target control of zoonoses, intervention in companion animals and changes in animal production, with an impact on animal welfare, human health or on the environment.

Currently, economics are not routinely used during implementation, and this potentially leads to less than efficient outcomes from animal health, welfare and production programmes. Cost-benefit analysis can be considered too unwieldy a tool for the implementation phase, as too much time is needed for the estimation of benefits, which requires epidemiological modelling to determine risk factors for disease, examination of the impact of the presence of disease on production and, for wide-scale programmes, the need to consider impacts on markets. What is needed is a simpler list of technical outcomes that are, or can be, reasonably measured. Cost-effectiveness analysis could add significant value to this stage, as it focuses on technical parameter outcomes that would influence a monetised estimation of economic profitability.

As with CBA, challenges for the use of CEA in the assessment of interventions in animal health, welfare and production include setting the outcomes of interest and the availability and quality of data. These challenges have not been addressed by looking more carefully at how data collection can be improved but by increasing the complexity of simulations of the real world. Many of the models generated are based on limited data sets and very often are not validated against real scenarios. In essence they represent 'best guesses' but are often presented as scientifically objective. More work is required on improvement of existing structures of outcome estimations or on simplification of the estimated outcomes to what can be reasonably measured within the resources available.

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Table I

Examples of published studies using cost-effectiveness analysis in assessments of animal health, welfare and production

Reference	Description	Methods	Outcome of interest
(26)	Explores the variation of greenhouse gas emissions on commercial dairy farms and in the farmers' preferences for mitigation options	Modelling using data collected from questionnaire	Emissions per kg of milk
(27)	Estimates the health and economic consequences of non-compliance with antimicrobial treatment of canine skin infections	Costs determined using market prices; effectiveness determined by modelling	Toxicity and time without symptoms
(28)	Assesses the sensitivity and cost-effectiveness of surveillance for avian influenza in wild birds	Scenario tree analysis used to estimate sensitivity of the surveillance system; costs determined using market prices	Monthly probability of detection
(29)	Assesses the cost-effectiveness of various surveillance streams to optimise the surveillance system for bluetongue	Costs determined using market prices (cost analysis); effectiveness determined using scenario tree modelling	Component sensitivity
(30)	Estimates the cost-effectiveness of pimobendan compared with benazepril for treatment of myxomatous mitral valve disease in dogs in Switzerland	Cost and benefits determined using modelling	Additional days of life
(31)	Estimates the cost-effectiveness of pimobendan compared with generic benazepril for treatment of myxomatous mitral valve disease in dogs in Germany	Cost and benefits determined using modelling	Additional days of life
(32)	Investigates the effect of various interventions in the reduction of *Salmonella* in the pig meat chain	Cost determined using market prices; effectiveness determined by modelling (quantitative microbial risk assessment)	Human cases prevented
(33)	Assesses the cost-effectiveness of bovine spongiform encephalopathy control strategies in the European Union	Modelling to determine effectiveness; cost calculated using literature data	Life years saved

(34)	Compares the effectiveness of dog vaccination strategies in terms of coverage and cost in different community settings in Tanzania	Epidemiological study (questionnaire) to determine coverage; cost determined using market prices	Vaccination coverage; cost per dog vaccinated
(35)	Determines the probability of introducing Aujeszky's disease virus (ADV) in areas under control and eradication programmes and estimates the cost- effectiveness of current control measures	Effectiveness assessed with risk assessment; cost calculated using literature data	Reduction in the probability of introducing ADV-infected animals
(36)	Evaluates the cost-effectiveness of management changes to control Johne's disease in infected dairy farms	Effectiveness data collected in a longitudinal study; costs collected using a questionnaire	Potential benefits of the control programme expressed in monetary terms
(37)	Evaluates the S*almonella* control programme comparing different strategies for *Salmonella* reduction	Effectiveness determined by modelling; costs calculated using market prices	Reduction in prevalence
(38)	Compares the cost-effectiveness of decontamination technologies in pig abattoirs	Effectiveness determined by modelling; costs determined using literature data	Reduction in the *Salmonella* risk indicator
(39)	Compares different testing strategies for detection of paratuberculosis	Effectiveness determined by modelling; costs calculated using market prices	Herd sensitivity
(40)	Assesses the cost-effectiveness of alternative strategies to increase food safety on dairy farms	Effectiveness determined using expert opinion; costs calculated using partial budget analysis	Food safety coefficient
(41)	Evaluates the cost-effectiveness of targeted sampling *versus* random sampling for classification of herds infected with paratuberculosis	Effectiveness determined in epidemiological studies and simulation; costs calculated using market prices	Detection probability (herd sensitivity)
(42)	Estimates cost-effectiveness and cost-utility of interventions to control *Campylobacter* contamination of broiler meat	Modelling and risk assessment	Reduced campylobacteriosis cases and disability-adjusted life years
(43)	Determines the cost-effectiveness of measures for prevention of classical swine fever	Effectiveness determined using scenario tree modelling; cost determined from information in the literature	Reduction of the probability of introduction

(44)	Compares the costs of various sampling strategies to estimate the prevalence of antimicrobial resistance in *Campylobacter* in poultry	Effectiveness determined by modelling; costs determined using partial budget analysis	Precision of prevalence estimate
(45)	Estimates the cost-effectiveness, economic benefit and distribution of benefit of improving human health in Mongolia through the control of brucellosis by mass vaccination of livestock	Calculation of disability-adjusted life years; costs based on the budget of the Ministry of Agriculture; cost-benefit analysis	Disability-adjusted life years

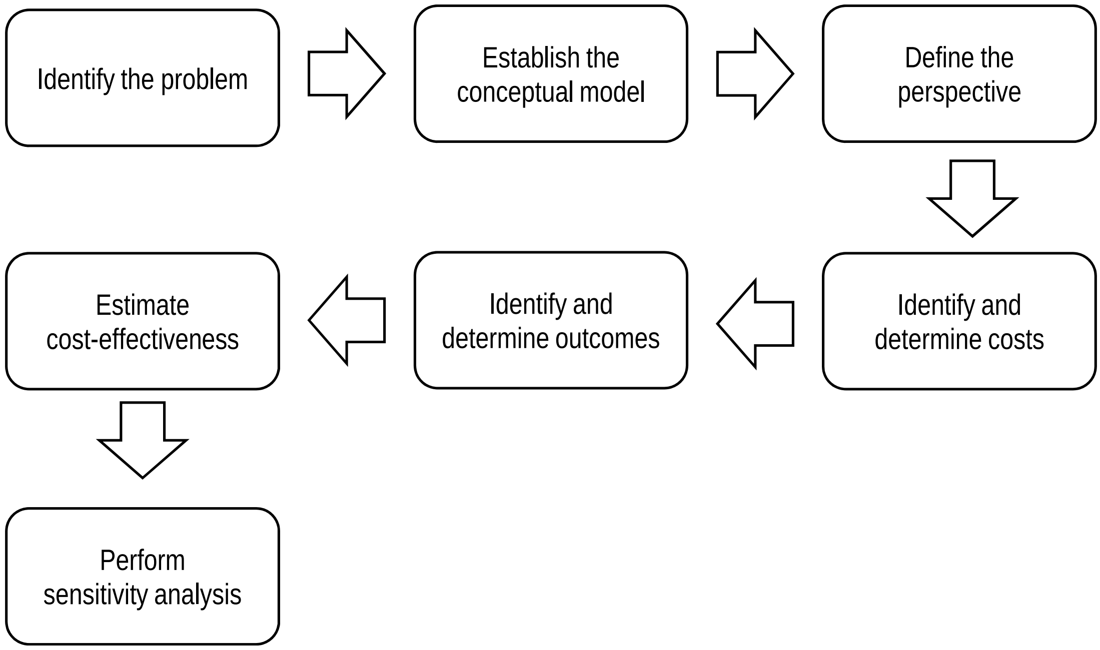

Fig. 1

Steps in cost-effectiveness analysis

Adapted from Petitti (5)