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A guide -

Introduction to the use of Cost-Effectiveness Analysis in Animal Health

By

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Summary

Cost-effectiveness analysis (CEA) is a form of economic analysis that compares the relative costs and effects of two or more courses of action. CEA is used extensively as a framework to assist resource allocation decisions in areas such as human health care. Conversely, for animal health, economic analysis is not so commonly performed and the preferred tool has tended to be cost-benefit analysis (CBA). A more widespread uptake of CEA in animal health offers a simpler way to raise the use of economic analysis in animal health decisions. This paper sets out a methodology for applying CEA to animal health. It reviews the use of CEA in related areas and the role of this technique in animal health, welfare and production assessments. CEA can add further value to programmes targeting animal welfare or animal diseases with an impact in human health, situations where the outcomes can best be quantified in physical terms rather than using monetary values. Importantly, CEA can readily be performed during programme implementation stages to assess alternative courses of action in real time.

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Economic analysis as an appraisal tool in project management

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

For economic analysis to be used effectively, they should be integrated within a project management structure such as that provided by the ROAMEF cycle (Figure 1) [4]. Embedding appraisal in a cycle maximizes the likelihood that programme activities are updated as a better evidence base is developed. The ROAMEF cycle includes building on a clearly stated rationale for the activity and setting measurable objectives or outcomes against which the effectiveness of the intervention can be assessed. Economic analysis should not simply be used on a one-off basis; lessons learned must be followed through into revisions to implementation and the analysis must be updated throughout the implementation and evaluation phases of the project. Finally, feedback on lessons learned should be shared.

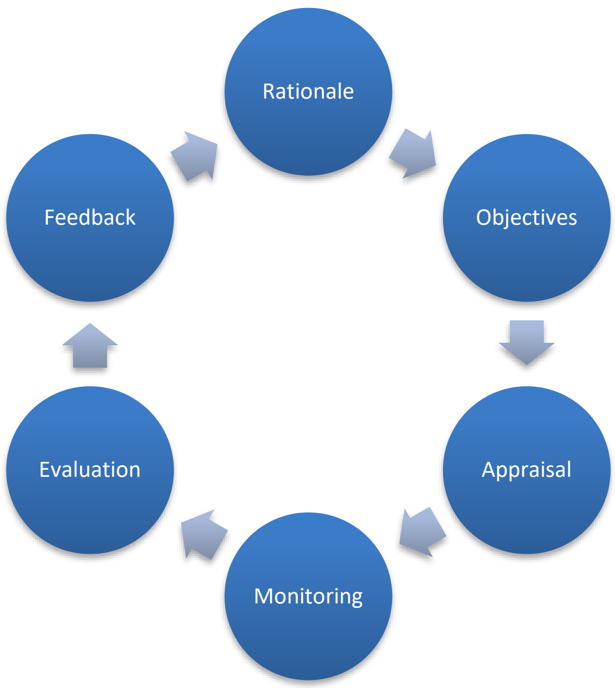

Figure 1. The ROAMEF cycle [4].

Commonly applied economic analysis methods

Different economic analysis tools based on a range of economic theories are available according to the objective being pursued. Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) are the most commonly used forms of economic appraisal in healthcare and animal health settings.

CBA uses monetary units to quantify costs and outcomes and has a broader scope of application than other types of analysis, informing 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 resulted in a limited use of CBA in human health and in other areas [5-7]. In animal health, cost-benefit analysis involves uncertainty in the estimation of populations (scale) and disease levels (prevalence) and the need to estimate the value of the animals and products they produce.

Some animal product may be difficult to value:

- Pet animals
- Sport animals
- Animal Welfare

By contrast, cost- effectiveness analysis removes the need to place monetary values on outputs, potentially freeing up time and resources to focus on improving the measurement and estimation of the technical outcomes. This is done by measuring benefits in the units most appropriate to describe the intended intervention effect, rather than in monetary terms, while program costs are calculated in monetary terms. A comparison of the ratio of effect to monetary cost therefore provides a cost-effectiveness ratio. Cost-effectiveness ratios of different programme options can therefore be directly compared, and interpreted directly by decision makers by application of an external standard such as a budget constraint or threshold, for example, cost per life-year saved [1, 3, 8].

Economic analysis can be applied in three ways to inform animal health decision making: to justify a defined strategy - *ex-ante* analysis, to assess the impact of an on-going programme, or to assess the impact of a past programme - *ex-post* analysis [9]. CBA has to date been the preferred tool for *ex-ante* and *ex-post* economic evaluation in animal health[10]. During the implementation stage, CBA has shown its limitations, being considered unwieldy [11] as significant time is required to collect the requisite data and perform the calculations to convert program outcomes into monetary values. Cost-effectiveness analysis could add significant value to this stage, as it focuses purely on technical parameter outcomes. 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 longest period of most animal health projects.

This paper reviews the fundamentals of CEA, its application in the related field of human health, and addresses its present use and the potential added value in animal health, production and welfare interventions. In addition to outlining the role of CEA, this paper includes a step by step methodology and framework for applying CEA to animal health issues.

The framework for cost-effectiveness analysis

Why use CEA?

CEA helps identify the most economically efficient way to fulfil an objective or outcome. It assesses the effectiveness of an intervention through the outcomes achieved, but without placing monetary values on the outcomes.

It can help answer questions such as:

- How much does an intervention programme cost, either overall or for a particular component?
- How effective is a particular intervention?
- What other options are available to achieve the desired outcome and how effective are they?
- What intervention or group of interventions gives the best outcome?

CEA does not of itself provide evidence that the projects are economically worthwhile, only that they have a range of cost-effectiveness ratios. But by ranking according to cost-effectiveness ratio, it is possible to ensure that the spending on a given programme provides the highest overall return until the budget is exhausted. It also follows that going forward, any new project should not be considered unless it provides a higher rate of return (as measured by the Cost Effectiveness Ratio) than the project it is replacing.

Introduction

CEA is a commonly applied tool in the field of human health economics, used to investigate potential improvements to the allocation of resources within human health interventions (Pettitti, 2000). There are a number of steps involved in a cost-effectiveness analysis: initially stating the problem, identifying possible intervention options, costing these options, and determining the desired outcomes. By combining costs with outcomes, cost-effectiveness analysis turns costs and benefits into values that allow comparison to be made between different options by using effectiveness metrics as a denominator. The selection of appropriate effectiveness metrics should be based on the interests of the people making resource allocation decisions. If used within an economic framework, cost-effectiveness analysis therefore provides evidence for decision-making, facilitating improvements in resource allocation to achieve a defined goal

Applications of CEA in the literature

A review of the medical literature published by Hutubessy *et al.* [5] revealed that between 1990 and 2000 on average 497 papers per year were published on CEA, showing that in the human health sphere CEA are largely more common than CBA studies. CEA has been used to inform decisions on the allocation of health-care resources and the prioritisation of interventions at the patient level and for both private and public health-care systems [12]. Besides human health, CEA has been applied in many other disciplines where valuing outcomes in terms of natural effects has a methodological advantage, including ecology and the environment, energy, and transport [13].

Current role of CEA in animal health, welfare and production assessment

CEA has been favoured in human health research, as the method negates the need to apply monetary values to morbidity and mortality outcomes, resulting in an exponential trend in application [5]. In the field of veterinary medicine however, the technique is not applied as commonly as a basis for decision making. CBA and cost analysis have, in contrast, been more widely used [10, 14-19], as it is possible to place a value on the majority of mortality and morbidity impacts of animal disease.

Published studies on the use of CEA in the field of animal health intervention have been most often performed to analyse programmes focusing on the control of zoonotic diseases, but also to assess the cost-effectiveness of diagnostic tests and measures for disease introduction prevention. Most papers perform an *ex-ante* analysis comparing alternative strategies to achieve an effect. Outcomes of interest vary widely from life years gained, to reduction in risk or increased sensitivity of a diagnostic test.

An example of a recent application of CEA for an animal health, welfare and production assessment is given by Lyons *et al* [46]. In this study, the authors evaluated the cost-effectiveness of a series of interventions for the control of Escherichia coli (VTEC) on UK dairy farms. The epidemiological information and selection of interventions to be assessed in the study were given by a previous randomized control trial [20], converted to the attributable fraction of prevalence reduction if the intervention measure(s) were implemented. The authors developed cost models for the interventions, considering the measures both individually and in combination. Subsequently, the cost-effectiveness ratio was calculated as the intervention cost per dairy cow divided by the attributable fraction of prevalence reduction. To illustrate the difference between CBA and CEA, the effect chosen by the authors focuses on change in a technical outcome, prevalence reduction, but the benefits that does not require monetisation. Further details of published animal health CEA studies together with and the outcome (or effectiveness) measures used are provided in Annex 2.

Well conducted CEA provides a source of information to inform policy setting and prioritisation exercises [3, 21]. Similarly, as has occurred in human health, it is likely that CEA will become increasingly applied in animal health, production and welfare assessments, emphasising the importance of understanding the method, strengths and limitations of this tool.

Methodological steps for cost-effectiveness analysis in animal health

This section sets out the general methodological approach for undertaking CEA. A series of steps are required to reach a cost-effectiveness ratio that allows a comparison to be made of the available options (Figure 2).

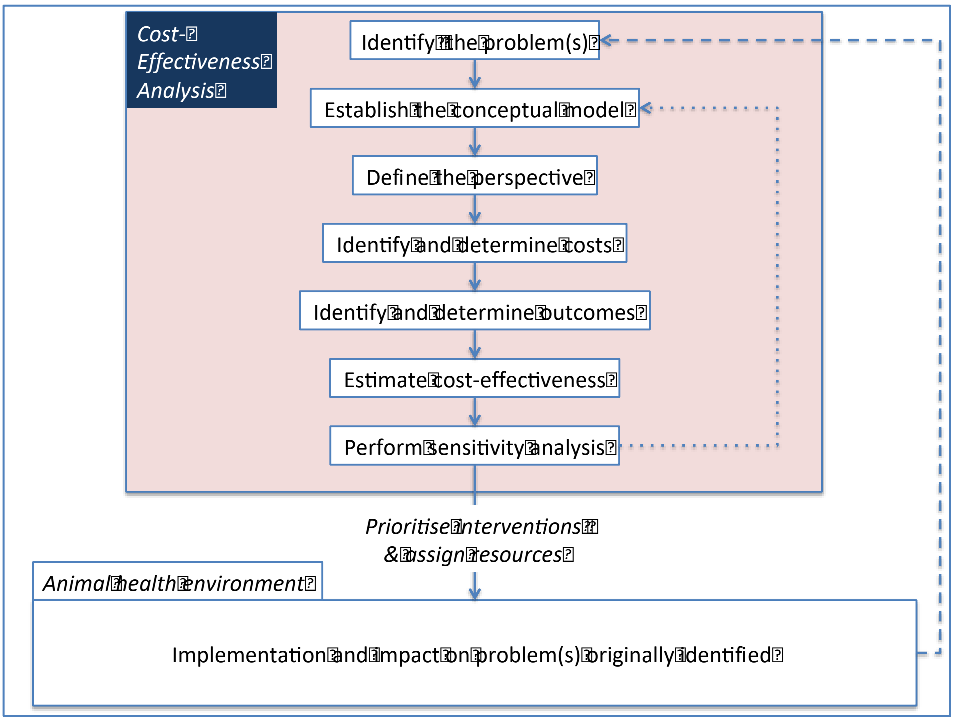

Figure 2. Steps of cost-effectiveness analysis and its links to decision-making and the animal health environment (note: there should be feedback loops)

Identifying the problem and establishing the conceptual model

Identifying the problem, the intervention and its alternatives is the first step of the analysis. CEA is concerned with finding the most efficient way of achieving a defined goal. It is essential that the problem to be addressed in the CEA is well defined at the outset, in order to set the scope of the analysis and to identify the range of potential options and their impacts. The conceptual model, outlining the full range of events arising from the intervention, is frequently shown using a decision tree [6]. Where no clear outcomes can be defined, CEA is not suitable for use as an appraisal tool.

As part of this process it is important to clearly define the "counter-factual", or baseline, for the analysis. This is the alternative course of action against which the intervention is compared. Having a clear understanding of the counter-factual is required in order to estimate changes both to costs and to the outcomes that result from the intervention. Commonly applied counter factual scenarios include maintenance of currently applied control measures, or taking no action whatsoever.

Part of the problem definition and conceptual model is determining the outcomes of interest. In a CEA this often requires integration of the perspectives of all stakeholders with decision making responsibilities for the project. Taking the input of stakeholders at this formative stage of the analysis maximises the likelihood of CEA producing outputs of direct relevance to decision makers, maximising the utility of the analysis.

Typical outcome measures could be:

- Changes in time to detection for disease incursion
- Reduction in disease prevalence
- Reduction in human cases of zoonotic disease

Establish the analytic perspective

The analysis can be undertaken from a number of different perspectives as the people involved may take different views on the most advantageous policy [3]. Usually CEA takes either the societal or the programme perspective with costs and benefits of the interventions valued differently [6, 8]. In the programme perspective only outcomes and costs experienced within that programme are taken into consideration [8, 22], whereas in the societal perspective, all significant outcomes and costs are considered, independently of who pays or benefits from the effects [8].

Identify and determine costs

Total direct costs are used as the top line (numerator) of the cost-effectiveness ratio. This includes 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 [8].

It is important to define and measure costs clearly to ensure a consistent and robust approach. In human health, methodological guidelines clearly establish the categories of cost that should be considered in the calculation of total direct costs. Direct health costs, such as tests, drugs, personnel and rent and also costs of patient time expended with the intervention should be included. Additionally, costs associated with caregiver's time and direct non-health care costs should also be considered [3, 6, 8].

Micro-costing techniques, where the correct monetary value of every input used is enumerated, provide an option to value costs but can be time-consuming, and therefore uneconomic. As a result, gross costing, where estimates of costs are obtained, is more frequently used [6].

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 [3] and both costs and benefits when spread over time should be discounted and take inflation into consideration [6].

Costs can be classified in various ways, for example:

- By **input type**– cost of labour, medicine, capital (buildings, etc.)
- By **activity**- planning, administration, supervision, or
- By **organizational level** -national, regional, local

There are advantages and disadvantages to each method of classification, largely depending on what breakdown of information is most useful for understanding or tracking the relevant costs. The most important point is to ensure all the relevant costs are included and that they do not overlap (so they are not omitted or counted twice).

Real v Nominal prices

It is important to ensure costs are measured and expressed in a common unit of currency and price base, to avoid problems that can arise due to prices changing over time due to inflation. CEA is usually undertaken in "real terms" (i.e. adjusted for inflation) rather than in "nominal" prices (i.e. where price have not been adjusted for inflation).

Discounting

Where a programme lasts more than one year, it is usual to take this into account by using discounting to adjust and combine the streams of current and future figures into one number (known as the Present Value). Discounting is carried out by applying a discount rate to future years, chosen to reflect the value placed on the difference between the current and future use of resources. A range of real annual discount rates (often between 3%-12%) are commonly used by different countries and international organisations in their economic appraisals. (These rates are described as "real" to reflect the fact that the prices and values used in the appraisals have already been adjusted to remove the impact of inflation). However the appropriate discount rate will vary reflecting the circumstances of a project, its location and time frame. Advice should therefore be sought on selecting appropriate discount rates to use. Further detailed guidance on applying CEA is published by a range of organisations including WHO, the EU, the World Bank and NICE [50-53].

Identify and determine outcomes

Effectiveness estimations constitute the bottom line (denominator) of the cost-effectiveness ratio [8] and a vast range of measures of effectiveness can be used reflecting the diversity of effects [3].

In human health, common outcomes 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) [23]. These can be measured across various interventions allowing for comparison.

The data required to evaluate effectiveness can come from different sources depending on the stage of the project lifecycle at which the analysis is being performed (see Annex 2). *Ex-ante,* data might be sourced from randomised control trials or observational studies. Mathematical models and Bayesian analysis can provide lower-cost options for estimating outcomes of different intervention scenarios [3]. Later within the project cycle, data collection mechanisms can be integrated within the fabric of the project to allow more accurate analysis to be performed, and to validate prior modelling work. Yet, as with the problems of estimating monetary benefits for an animal health CBA, primary data collection can be resource consuming, thus the extent of primary data collection necessary to substantiate claims of project efficacy will need to be assessed on a case by case basis.

Estimate cost effectiveness and perform 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 under two forms. As an average ratio, where:

$$CE\ ratio = \frac{Cost\ of\ the\ intervention}{Effectiveness\ of\ the\ intervention}$$

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

$$CE\ ratio = \frac{Cost\ intervention - Cost\ of\ baseline}{Effectiveness\ intervention - Effectiveness\ of\ baseline}$$

Incremental cost-effectiveness ratios [12] 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 [5]. Importantly, incremental comparisons should be made with the next best option to avoid distortions in the calculations [3, 24].

Sensitivity analysis should assess the effect of the various assumptions made in the analysis on the conclusion [3]. Sensitivity analysis addresses any uncertainty in the data inputs used to derive the CE ratios, for example, where technical parameters are derived from point estimates that are subject to measurement error, or, particularly in ex-ante analysis, to explore how robust CE estimates are to possible changes in price of project cost items. As the project moves from planning to implementation, the results of implementation should be captured to provide additional data to refine the CEA, creating a feedback loop which allows revision of the implementation.

The interpretation of CEA ratios

While increasing the use of CEA in the appraisal of animal health programmes offers potential opportunities, decision-makers who are unfamiliar with the method may require guidance on the interpretation and application of CEA results.

Of primary concern is the consideration of context when interpreting the results of CEA studies. While CEA aids decision-making, it is not sufficient in itself for making complex resource allocation decisions as it does not incorporate aspects of overall budgetary impact or technical feasibility. To compare the output to that of a CBA, where a benefit-cost ratio greater than 1 has an implicit connotation of profitability, the ratios produced by CEA do not inform as to the absolute value of a given intervention, but how the intervention performs relative to others and within its context. This is tied to the fact that judging the value of a cost-effectiveness ratio, for example cost per year of life gained, requires attention to societal values such as equity and fairness [3, 25]. In many cases, there is no obvious threshold dividing an acceptable from a non-acceptable cost-effectiveness ratio and this fact is considered a constraint in the application of CEA. To illustrate this point, take the example where a surveillance system for a disease such as scrapie, with potential zoonotic risk, is being evaluated [26]. In such a case, the economic value of risk reduction through improvements to surveillance and removal of infected animals is difficult, if not impossible, to quantify. The result is that a degree of subjectivity in interpretation is possible when thresholds of acceptability are not built in to the analysis technique.

In human health, acceptability thresholds have been developed in an attempt to remove subjectivity from the interpretation of CEA and the harmonisation of methodologies to enhance comparability of studies has been promoted by national and international organisations [8], although methodological variations continue to occur [12]. Thresholds are generally applied at national level, and are strongly linked to the prosperity of the country where decisions are being made, confounding the possibility of defining common international interpretation frameworks [3, 12]. Furthermore, these acceptability thresholds are frequently challenged and arguments made for their revision [27-29]. Further expansion of the use of CEA in animal health would therefore necessitate the evolution and development of commonly applied standard metrics for measuring outcomes, which would then need to develop their own acceptability thresholds within each context in which they are applied.

Other controversial aspects of the analysis relate to ethical concerns arising from valuing natural effects, including health and human life. Discounting benefits for instance, implies that an effect observed in the present is more valuable than if observed in the future [25] and these challenges are not exclusive to CEA, but rather a function of applying any economic analysis to systems with non-economic outputs. Again, these assumptions in the analytical method and output metrics used are frequently revisited and revised [30-32].

Conclusions

Currently CEA is widely used in assessing human health interventions but not used systematically to inform animal health decisions. CEA does however offer a user-friendly economic tool, as its use of effectiveness measures can be tailored to reflect the interests of people involved in the decision-making process. Simultaneously, less intense in its data and computational requirements than CBA and therefore is more appropriate for real-time project appraisal and decision making as part of a structured project cycle.

Cost-effectiveness analysis requires multi-disciplinary teams - veterinarians, disease control experts, epidemiologist, economists – to measure the contributions of prevention and control interventions to overall outcomes of disease strategies and policies. This note has set out the steps necessary to undertake CEA for animal health decisions. Through the application of cost-effectiveness concepts and models the allocation of scarce resources can be improved during the implementation animal health programmes and projects. Additionally, publishing the results of such work as widely as possible would enable the evidence to be more comprehensively understood and acted upon.

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Annex 1

Cost- Effectiveness Checklist: An aide-memoire

Programme Title:	Completion
Identify the problem and establish the conceptual model **What is the problem being addressed?** **What is the goal?** **Define the desired outcome.**	
Establish the analytic perspective **What approach is being used- societal or programme only? (i.e. scope of costs and impacts that are included)**	
Identify and estimate costs **What items need to be included and costed in association with the intervention?** **What is the counterfactual against which the option is compared?** **What are the alternative options?** **What is the source of the costings and how robust are they?**	
Identify and estimate outcomes **What are the estimated outcomes?** **How have they been derived?** **Over what timeframe do they occur?** **How certain are the results?**	
Estimate cost effectiveness and sensitivity analysis **Calculate cost effectiveness: Cost of intervention/effectiveness of intervention** **Undertake sensitivity analysis: How robust are the results?** **What are the key assumptions?**	
Feedback **What Follow up actions are required?** **How will the results be used /shared to help improve and inform future decision making?**	

Annex 2

Examples of published studies using CEA in animal health, welfare and production assessments

Reference	Description	Methods	Outcome of interest
[33]	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
[34]	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	Time without symptoms and toxicity
[35]	Assesses the sensitivity and cost effectiveness of wild birds surveillance for avian influenza Implementation	Scenario tree analysis used to estimate sensitivity of the surveillance system Costs determined using market prices	Monthly probability of detection
[36]	Assesses the cost-effectiveness of different surveillance stream to optimise the surveillance system for Bluetongue	Costs determined using market prices (cost analysis); effectiveness determined using scenario tree modelling	Component sensitivity
[37]	Estimates the cost-effectiveness of pimobendan compared to benazepril for treatment of myxomatous mitral valve disease (MMVD) in dogs in Switzerland	Cost and benefits determined using modelling	Additional day of life
[38]	Estimates the cost-effectiveness of pimobendan compared to generic benazepril for treatment of MMVD in dogs in Germany	Cost and benefits determined using modelling	Additional day of life
[39]	Investigates the effect of different 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
[40]	Assesses the cost-effectiveness of BSE control strategies in the EU	Modelling to determine effectiveness; cost calculated using literature data.	Life years saved
[41]	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
[42]	Determines the probability of introducing Aujeszky's disease virus (ADV) in areas under control and eradication programme and estimates the cost-effectiveness of the current control measures	Effectiveness assessed with risk assessment; cost calculated using literature data	Reduction in the probability of introducing ADV-infected animals
[43]	Evaluates the cost-effectiveness of management changes to control on Johne's disease in infected dairy farms	Effectiveness data collected on a longitudinal study; costs collected using a questionnaire	Potential benefits of the control programme expressed in monetary terms

Reference	Description	Methods	Outcome of interest
[44]	Evaluates the Salmonella control programme comparing different strategies for salmonella reduction	Effectiveness determined by modelling; costs calculated using market prices	Reduction in prevalence
[45]	Compares the cost-effectiveness of decontamination technologies at the pork abattoirs	Effectiveness determined by modelling; costs determined using literature data	Reduction in the Salmonella risk indicator
[46]	Compares different testing strategies for detection of paratuberculosis	Effectiveness determined by modelling; costs calculated using market prices	Herd sensitivity
[47]	Assesses the cost-effectiveness of alternative strategies to increase food safety on the dairy farm	Effectiveness was determined using expert opinion; costs were calculated using partial budget analysis	Food safety coefficient
[48]	Evaluates the cost-effectiveness of targeted sampling versus random sampling for classification of herds infected with paratuberculosis	Effectiveness determined by epidemiological studies and simulation; costs calculated using market prices	Detection probability (herd sensitivity)
[49]	Estimates cost-effectiveness and cost-utility of interventions to control Campylobacter contamination of broiler meat	Modelling and risk assessment	Reduced campylobacteriosis cases and DALYs
[50]	Determines the cost-effectiveness of different measures for classical swine fever prevention	Effectiveness determined using scenario tree modelling; cost determined collecting information in the literature	Reduction of the probability of introduction
[51]	Compares the costs of different 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
[52]	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 DALYs. Costs were based on the budget of the Ministry of Agriculture. Also CBA	DALYs
[26]	Estimates the cost-effectiveness of surveillance options for transmissible spongiform encephalopathies of sheep and cattle in Great Britain.	Surveillance option outcomes estimated through modelling, costs extrapolated from current surveillance costs.	Diseased animals entering food-chain, time to detection of disease re-emergence.