National and international impacts of animal diseases

A. James

Summary

It is not useful to attempt to estimate the total cost of animal diseases. The impact of animal disease can only be assessed in terms of the costs and benefits of alternative practical disease control policies. The techniques used in animal disease economics are reviewed and their potential value in decision-making discussed. The direct and indirect economic impacts of animal diseases and control programmes are discussed.

Keywords

Animal diseases, Animal disease economics, Economics, Exotic animal disease, Risk analysis

Impatto nazionale e internazionale delle malattie animali

Riassunto

Cercare di valutare il costo totale delle malattie negli animali non è produttivo. L'impatto delle malattie animali può essere valutato solo in termini di costo e beneficio di politiche di controllo alternative. Vengono illustrate le tecniche usate nella valutazione economia della malattia nell'animale e discusso il loro valore potenziale nelle decisioni da prendere. Si discute sugli impatti economici diretti e indiretti delle malattie animali e dei programmi di controllo

Parole chiave

Analisi del rischio, Costi delle malattie animali, Economia, Malattie animali, Malattie esotiche.

Introduction

In this paper, a review is made of the various economic impacts of animal diseases. Economic impact is much greater than financial impact and includes all effects that have value to humans, whether or not they can easily be measured in monetary terms.

It is important to measure the economic impact of animal diseases to improve the decision-making process for establishing animal disease policy.

Economists are sometimes asked to rank diseases in order of the economic losses that they cause, but this ranking is of no value in policy-making. The total cost of an animal disease would be of no practical interest: eradication of most animal diseases cannot be contemplated. Many of the most important diseases are not present in many countries, so they are causing no economic loss beyond the costs of prevention. Nevertheless, prevention of exotic diseases is a key disease control policy for most countries.

What is required for decision-making is the net economic impact (the benefits minus the costs) of any proposed change in animal disease control policy. Then the policy should be to direct disease control resources at the activities that produce the greatest benefit for each unit of cost. However, the benefits are often difficult to measure for two reasons.

Firstly, there are always uncertainties regarding the effect of any policy on the incidence and severity of a disease. This is particularly the case

The University of Reading, Veterinary Epidemiology and Economics Research Unit,
School of Agriculture, Policy and Development, P.O. Box 237, Reading RG6 6AR, United Kingdom
aj@panveeru.net

for epidemic diseases which, by their very nature, have the potential to spread rapidly. Moreover, minor and unpredictable influences, such as the decisions of an individual livestock owner or weather patterns, can have major effects on the progress of an epidemic, especially in its early stages.

Secondly, animal diseases can have a very wide range of effects, including many that are difficult to value in monetary terms. If costs and benefits are to be compared directly, they have to be valued as a common monetary unit. Valuation of commodities such as meat and milk, for which markets exist, is usually straightforward. However, effects on animal welfare and human health are much more difficult to value in monetary terms. People value these effects differently. Some people place a much higher value on animal welfare than others. The human victim of brucellosis is likely to place a much higher value on the cost of this disease than would be the case for people not directly affected by brucellosis.

These problems of measurement are less acute in economic analysis at the level of individual herds than for national analysis. This is because more information is available on how a particular control policy will affect the incidence of disease. Problems of valuation also tend to be less acute. For private decision-making purposes, the livestock owner will usually base decisions principally on the direct financial costs and benefits, although such issues as animal welfare may also influence decisions.

Although this paper is concerned with national and international economic analysis, many important diseases can only be effectively controlled by herd management strategies and are certainly of national economic importance. For example, in most dairy industries where bovine tuberculosis and mastitis both occur in a herd, mastitis probably causes much greater economic loss. It is also a cause for public concern because of its implications for animal welfare. For these reasons, governments are increasingly making policies with respect to the control of diseases, such as mastitis, for which control policy had traditionally been left to the livestock owner.

Financial analysis at the level of individual producers is an essential part of any national economic analysis of animal diseases. It is necessary to know the implications of national policies for individual producers in order to determine any financial compensation rates that may be appropriate. Livestock owners cannot be expected to cooperate in the implementation of national policies that have adverse financial effects on them.

Techniques

Epidemiological models

Whenever an economic analysis of animal health policy is undertaken, an epidemiological model is implied. This is the case for both evaluations of future decisions (ex-ante assessment) and of decisions or events that occurred in the past (ex–post assessment). It is necessary in ex-ante assessment to make assumptions about the effect of any policy on the pattern of disease in the population. Similarly, in ex-post evaluation it is necessary to make assumptions about the outcome if an alternative policy had been adopted. These models range from the purely conceptual, to simple extrapolation of results from a sample to the entire population, to complex computer models. All bring benefits and risks to the analysis.

A large number of formal epidemiological models have been developed, and some have been used to guide disease control policy, both at national and individual herd levels. Sometimes these have been linked to formal economic analysis of the predicted outcomes, but even where formal economics has not been used, economic evaluation is implicit: the preferred policy would be the one that produced the best economic outcome.

Recent applications of epidemiological models have highlighted the fact that it is difficult or impossible to estimate some of their parameters, especially those relating to frequency of contact between animals or herds. In any case, such contact rates vary according to local conditions and over time. Usually epidemiologists are forced to use 'guesstimates' of these parameters and the result is that the model will simply forecast their own preconception of the progress of the disease. For example, if the modeller judges that short-distance spread is more frequent than medium-distance spread, the model will predict that such policies as ring-vaccination or pre-emptive culling will be relatively effective. In the opinion of the author, this constitutes a serious lack of objectivity and the risks are especially severe when decision–takers do not understand the logical basis on which the forecasts are being made.

An example of this situation is to be found in the United Kingdom foot and mouth disease epidemic of 2001. A detailed description of policy development at the time, and the influence of epidemiological models in the process, can be found in Kitching *et al.* (7). One model in particular, that of Ferguson *et al.* (2), played a key role in the decision leading to the contiguous cull policy. A newspaper article from the time reproduces outputs from the model under the caption 'scientific predictions' (4). However, this, and other models, contained simplifications and assumptions which heavily influenced the conclusions on appropriate control strategies (9). Critical assessment of the models within the government foot and mouth disease science group was difficult and discussion of their possible limitations did not appear to influence decision-making. One interpretation is that decision-makers were seduced by the illusion of truth provided by mathematics (3), with the result that the predictions of the models tended to be accepted without question, providing a ready-made solution to a decision problem.

It is much easier to develop epidemiological models of endemic diseases than of epidemics. The reason for this is that, particularly in the early stages of an epidemic, inherently unpredictable events have a dominant effect on the development of the epidemic. Stochastic modelling techniques, which incorporate the effects of chance, do not provide a complete answer to this problem. They tend to produce the answer that 'anything could happen', which is of limited value in economic analysis and decision-making. Furthermore, most models have to assume that the population of herds is homogeneous, or composed of homogenous groups of herds, with uniform contact rates. This is very far from reality.

Endemic diseases, on the other hand, are a much easier subject for epidemiological models. They are usually modelled within herds, where assumptions of homogeneity are more realistic. More data on critical factors, such as contact and transmission rates, are usually available. Despite the more predictable behaviour of endemic diseases, stochastic simulation is still important. One of the earliest applications of epidemiological modelling to disease control policy remains an excellent example. Hugh-Jones (5) developed a model of bovine brucellosis in the United Kingdom to ascertain why farmers were not joining the voluntary eradication programme. Brucellosis-free herds received a valuable premium on the milk price, but had to bear the cost of culling reactors. The model showed that, on average, there was a net gain for farmers joining the scheme, but also that there was a very small risk of an individual farmer suffering major loss. Stories of such rare cases of major loss in the farming press were sufficient to deter many farmers from the programme.

Epidemiological models do have a very important potential application in evaluating ex-post data to estimate actual transmission rates and evaluate the reasons for increased and reduced rates over time and space. In this way, it is possible to identify policies and conditions apparently influencing transmission rates, and learn lessons for future control and prevention strategies.

Perhaps the most valuable application of epidemiological models, including purely conceptual models based on diagrams, is to clarify understanding of the mechanisms of disease transmission and maintenance during the development of the model. The process of having to specify possible transmission pathways and interactions is often very instructive. Even where it is not possible to assign values to probabilities and frequencies, it is often clear that one transmission pathway is far more important than others and this can suggest more effective control strategies. A good example of such a process was a recent study to determine the duration of animal movement standstill regulations to contain the spread of exotic diseases such as foot and mouth disease (8). A relatively simple spreadsheet model was produced and, predictably, the model anticipated outcomes reflecting mainly the animal movement and disease detection assumptions supplied to it. However, examination of the model structure and the results made it clear that any movement standstill regulation was highly effective in containing spread, almost regardless of the duration. A clear policy recommendation emerged from the logic of the model, even though values of most of the parameters could not be estimated or predicted (10).

Risk analysis

When conducting economic evaluation of exotic disease prevention policy, it is necessary to estimate both the risk of disease introduction and the economic impact of an outbreak if it were to occur. Risk model-building software based on spreadsheets is widely available and relatively easy to use. However, it is very easy to make two types of error in constructing risk models. The first is to assume that successive event probabilities in the risk pathway are independent of each other. This is frequently not the case, and if there is a positive association between the two events (i.e. if the first event occurs, the second is also more likely to occur) then the joint probability of both events occurring obtained by multiplying the two probabilities will be an underestimate. These errors can be compounded through the model, producing serious errors in the risk assessment.

A second, even more serious criticism of many quantitative risk assessments is that there is no objective way of estimating many of the key event probabilities. In fact, these are not risks but uncertainties. Expert opinions may be sought, but these often conflict with the result that the outcome of the risk assessment depends on which expert opinion is believed.

Another difficult issue in quantitative risk assessment is the calculation of the economic cost of a risk. Usually, this is calculated as the product of the expected number of adverse events per time period and the average cost of such an event. The problem is to predict the cost of events, such as the introduction of an exotic disease agent. This could range from nothing to billions of dollars, depending on disease preparedness and, to a large extent, chance. To use the historical average cost of such rare events (even if any had occurred) would not be appropriate, as both the livestock industry and disease control services would be likely to have changed over the years.

Humans are by nature risk-averse. The perceived cost of a risk is often greater than the average loss per time period. This is especially true of exotic disease risks, where the potential losses are enormous to the economy as a whole, to individual producers and to the government officials responsible for making decisions on disease prevention and control. If the disease is introduced, animal health officials could be blamed for not protecting the livestock industry. In reality, veterinary services wish to pursue zero-risk strategies in relation to exotic diseases, and are likely to seek risk assessment results that would justify the banning of trade where they perceive any risk of exotic disease.

A more constructive approach to disease risk management could be provided by applying the methods of hazard analysis critical control points (HACCP) to the problem. This methodology was developed for the food processing industry, where the objective is to establish procedures, control points and monitoring that should eliminate the possibility of food contamination or other hazards. This approach is much better aligned with the real objectives of veterinary services. Where a risk or uncertainty is identified, even if it cannot be quantified, it can usually be prevented by appropriate controls and monitoring.

Many countries importing animal products already demand that exporters have HACCP systems in place to control food safety hazards and there seems no reason why similar measures could not control animal disease risks. The HACCP methodology is applicable not only to preventing the importation of exotic disease agents, but also to their containment in the importing country.

Economic effects of animal diseases

As stated in the introduction, disease control and prevention policy should be guided by comparison of the benefit of any policy change, in terms of the value of production, with the incremental control and prevention costs. Where a reduction in the level of control is contemplated, the benefits and costs may both be negative, but the comparison principle is the same.

In this section, human health and animal welfare impacts of animal diseases are considered separately from the animal mortality and production impacts. This is because of the problems of valuation referred to in the introduction. Logically, they should be valued and compared together with animal mortality and production impacts. However, the valuation of human health and animal welfare effects is essentially subjective. Therefore, in most economic analyses, they are considered separately so that the decision-maker(s) can apply their own subjective valuations in their decision-making process.

In analysis of national disease control policy, especially in relation to transboundary diseases, some of the most important costs and benefits may fall upon countries other than the one formulating the policy. A country that eradicates a transboundary disease may produce significant economic benefits for its neighbours and trading partners. Similarly, much of the cost of import restrictions to prevent the entry of exotic diseases falls upon potential exporting countries.

Mortality and production effects

When disease causes the death of an animal, there is the loss of the asset and the loss of its future production. The economic loss depends on the action of the owner. If the owner is able and willing to replace the animal by purchasing a replacement, the economic loss will be the cost of the replacement, any lost production in the interim and any costs of disposing of the dead animal. However, immediate replacement of dead animals is not always possible. Other owners may be unwilling to sell; in epidemics, replacements may not be available and owners might have to observe quarantine restrictions. If the dead animal cannot be replaced, the situation becomes more complex. The cost of any production losses would have to take into account the feed and other costs saved. In most cases, the losses would eventually cease as a replacement animal from within the herd became available. In practice, it is extremely difficult to make realistic estimates of these losses without recourse to computer models.

Where animals are used for traction purposes, their death (or temporary incapacity) can cause loss in other agricultural enterprises due to late cultivation, planting or harvesting of crops. It is very difficult to estimate such consequential losses. However, with the increasing availability of mechanical traction, it would often be possible for farmers to hire mechanical replacements. In this case, the loss would be the cost of doing so.

In many situations, livestock play an important role in farm economics as they represent most of the capital in the farming enterprise. They may, for example, be used as security for seasonal loans for crop enterprises. If the animals die, this can destabilise the finances of the entire farming household, with the economic impact far exceeding the value of the animals.

Most animal diseases result in reduced production of meat, milk, hair, wool, eggs, traction and other outputs of livestock enterprises. They may also reduce the quality, and therefore value, of what is produced. Consumer concerns during animal disease outbreaks or 'scares' may also result in reduced demand and very low market prices, thus reducing the economic value of what is produced. This effect can sometimes also occur when the risk to consumers is non-existent or negligible. For example, consumer demand for meat decreases during foot and mouth disease outbreaks, despite the fact that this disease does not affect humans. Even though these effects may be irrational, they still cause real economic loss.

Some diseases reduce production through reduced feed conversion efficiency of the animals. In other cases the effect may be through reduced feed intake of the sick animals. In the case of most diseases, including some gastrointestinal parasites, both effects probably contribute. Strictly, where production losses are associated with reduced feed intake, the calculation of economic loss should take into account the feed saved. However, in practice this would be very difficult to measure.

Herd models, either static or dynamic, can be helpful in calculating the mortality and reduced production costs of animal diseases e.g. James and Carles (6). Such models generally calculate a margin between herd output value and costs, using various production parameters. If the effect of the disease on production parameters is known, then all of the interactions in the production system are allowed for, and the true economic impact of the disease can be calculated. Problems of double–counting, e.g. allowing for production losses in dead animals are avoided. However, the results of such assessments can sometimes be counter-intuitive. For example, it is common to find that in milk-producing systems, calf mortality appears to be economically beneficial. This is because it is generally much more profitable to produce milk than to rear young stock. If the calves die, it would be possible to buy replacement heifers and keep more milk-producing cows.

Treatment and prevention costs

Treatment and prevention costs account for a large part of the economic loss incurred by many diseases, both at individual herd and national levels. The costs of purchasing and administering drugs and vaccines are simple to identify and evaluate, but to these must be added any costs of adverse reactions and product withdrawal periods, which can be significant, especially in milk production.

In the cases of exotic diseases (at national level) and diseases not present in individual herds, prevention costs account for all of the losses caused by the disease. Exotic animal disease prevention costs can be very wide-ranging. Costs are incurred by both the countries trying to prevent the entry of exotic disease, as well as those that are potential sources of infection.

Where exotic animal disease epidemics do occur and are controlled by stamping-out and quarantine measures, there are heavy direct costs in the value and destruction costs of animals slaughtered, disinfection and loss of production during quarantine. However, the indirect costs may be even greater: there are often environmental and animal welfare implications and rural industries, such as leisure and tourism, can also be severely affected. The costs of the 2001 foot and mouth disease outbreak in the United Kingdom were estimated at more than US$12 billion (1). A large part of this estimate related to losses in industries other than agriculture.

For countries free of the disease, there are direct costs to the authorities in maintaining border security facilities and personnel. The travelling public and importers of products suffer delays and inconvenience because of inspections. Port operators incur additional costs because of slower transfer of goods and people. In many cases, restrictions on trade in animal products are imposed to counter exotic disease risk. These result in economic loss to potential trading partners. Consumers in the would-be importing country pay more for animal products than would be the case if the trade were permitted. These national disease prevention costs are mirrored by biosecurity costs for individual producers, especially for the intensive producers of non-ruminant species.

It can be difficult to attribute the cost of measures to prevent introduction of disease to particular diseases, both at national and herd levels. Most disease prevention or biosecurity measures are effective against a range of diseases.

Producers in countries with transboundary diseases receive lower prices than would apply if more exports were possible. It is very difficult to produce realistic estimates of the economic effects of non-tariff barriers to trade. Such restrictions often result in retaliatory measures which extend the economic impact to other commodities. Furthermore, if producers have access to high-value export markets, they are likely to adopt completely different production systems to satisfy the demands of those markets. Thus, animal diseases can constrain the development of the entire livestock industry, at costs that can only be imagined.

Countries exporting animal products that suffer disease outbreaks resulting in temporary export restrictions face enormous economic and social costs. Major exporters of animal products, such as Australia, New Zealand and several South American countries, have developed animal industries almost entirely for supplying export markets. If these markets are suddenly closed, the export revenues are lost, and all of the people working in the processing industry are likely to be laid-off and lose their income.

As stated in the introduction, the total costs of disease treatment or prevention are not relevant to policy-making. What needs to be known for rational decision-making is the cost and benefit in terms of reduced disease or risk of disease of each control measure or package of control measures.

For the reasons given in the section on risk analysis, in the case of exotic epidemic diseases, the benefits are exceedingly difficult to measure with any accuracy. Firstly, there is rarely any information on which to base a quantitative assessment of the risk of a disease incident. Secondly, the cost of any disease incident could be trivial or massive, depending largely on unpredictable events, such as one farmer's failure to report disease. This is an area in which conventional economic analysis has little to contribute to rational decision-making.

However, economic analysis is used to compare the cost-efficiency of different risk prevention strategies. The reality is that an exotic animal disease epidemic is regarded as an event that must be avoided. If a risk pathway that could lead to such an event is identified, it can almost certainly be prevented by safeguard measures that would cost much less than an epidemic. These measures typically relate both to prevention of the introduction of disease, which cannot always be guaranteed, and prevention of spread in the event of an introduction. Economic analysis of alternative measures and combinations of measures can be used to select the most cost-effective policy. Most of these measures would be effective against a range of diseases, and so it could be of limited value to compare their cost with the risk and cost of a particular disease epidemic.

Human health impacts

Evaluation of the control of zoonotic diseases presents the particular problem of valuation of human sickness and mortality. The central problem here is that there is no agreement between different people on the value of a human life or suffering. Decision-takers at national level (politicians) are not usually prepared to state a cost of a human life. Decision-takers at herd level would usually place a much greater value on the lives of themselves and their family than of other people. Therefore it is not possible to produce an estimate of the cost of zoonotic diseases that would be of general relevance.

An approach that can assist in decision-making in economic assessment of zoonotic diseases is cost-efficiency analysis. It may be possible to calculate the disease control costs per life saved, or per case avoided. The decision-maker can then make a value judgement of whether this is worthwhile or not. The cost per life saved or case avoided can also be compared with an equivalent figure calculated for other possible investments, for example in the control of another zoonosis or a human disease, or even road safety improvements.

Animal welfare

Many animal diseases have significant impacts on animal welfare. This is as much the case for the common 'production' diseases, such as lameness and mastitis, as for more acute conditions. Disease control operations can also affect animal welfare. This is of particular importance in stamping-out operations, where large numbers of animals have to be killed in unsuitable on-farm conditions as quickly as possible.

Animal welfare is a subject of increasing public concern and legislation in many countries, suggesting that society places high values on animal welfare issues. As far as individual consumer behaviour is concerned, the indications suggest otherwise. It appears that most consumers are not prepared to pay a high premium for products that are labelled 'animal welfare friendly'. This might be because people do not have confidence in the assurance provided by the label. It could also be that, although they consider animal welfare to be important, they regard it as the responsibility of the authorities and other people. In some cases, they may give animal welfare a lower priority than their own economic wellbeing.

Conclusion

There is no doubt that animal diseases cause very large economic losses. However, there is no point in trying to estimate these losses in absolute terms. All of the economic techniques reviewed in this paper are designed to assist real decision-making on disease control policies that could actually be implemented. For example, it would be useless to estimate the worldwide losses caused by foot and mouth disease as a justification for a global eradication programme because, for logistical and technical reasons, such a programme could not be implemented in the foreseeable future. Neither would the worldwide estimate be useful in evaluating more limited control programmes. These would have to be assessed in terms of their implementation costs and the benefits expected to result from them (which would probably extend beyond the control programme area).

Economic analysis is essential to decision-making in animal disease control policy at national and international levels, but the use of the available methods is often constrained by lack of information and problems of valuation. The use of sophisticated epidemiological and economic modelling methods on inadequate data can carry dangers of giving decision-makers an unjustified sense of certainty.

References

1. Anderson I. 2002. Foot and mouth disease 2001: lessons to be learned inquiry report. The Stationery Office, London, 186 pp.
2. Ferguson N.M., Donnelly C.A. & Anderson R.M. 2001. The foot-and-mouth epidemic in Great Britain: pattern of spread and impact of interventions. *Science*, **292**, 1155-1160.
3. Gupta S. 2001. Avoiding ambiguity. Scientists sometimes use mathematics to give the illusion of certainty. *Nature*, **412**, 589.
4. Highfield R. 2001. Has the A-team defeated the virus? Scientific predictions. *Daily Telegraph*, 11 April, 25 (www.telegraph.co.uk/connected/main.jhtml?xml=/connected/2001/04/12/ecfoot12.xml accessed on 8 April 2006).
5. Hugh-Jones M.E., Ellis P.R. & Felton M.R. 1976. The use of a computer model of brucellosis in the dairy herd. *In* New techniques in veterinary epidemiology and economics. Proceedings of a symposium, 12-15 July, University of Reading (P.R. Ellis, A.P.M. Shaw & A.J. Stephens, eds). University of Reading, Reading, 90-106.
6. James A.D. & Carles A.B. 1996. Measuring the productivity of grazing and foraging livestock. *Agric Syst*, **52**, 271-291.
7. Kitching R.P., Thrusfield M.V. & Taylor N.M. 2006. Use and abuse of mathematical models: an illustration from the 2001 foot and mouth disease epidemic in the United Kingdom. *Rev Sci Tech*, **25** (1), 293-311.
8. Risk Solutions 2003. FMD epidemiological modelling project report – the silent spread model. A report for Defra, July 2003. Defra, London, 13 pp (www.defra.gov.uk/animalh/movements/costben/pdf/epidmodel1.pdf accessed on 25 July 2006).
9. Taylor N.M. 2003. Review of the use of models in informing disease control policy development and adjustment. A report for Defra. Defra, London, 94 pp (www.defra.gov.uk/science/Publications/2003/UseofModelsinDiseaseControlPolicy.pdf accessed on 25 July 2006).
10. Taylor N.M. & James A.D. 2003. Comparison of two cases where epidemiological modelling was used to support decisions regarding FMD control in UK. *In* Proc. Tenth International Symposium on Veterinary Epidemiology and Economics (ISVEE), 17-21 November, Vina del Mar. ISVEE, Santiago de Chile, CD-ROM.