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Economic analysis of animal disease outbreaks – BSE and Bluetongue disease as examples

Analyse der ökonomische Auswirkungen von Tierseuchenausbrüchen

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Summary

Although there is a long tradition of research on animal disease control, economic evaluation of control measures is rather limited in veterinary medicine. This may, on the one hand, be due to the different types of costs and refunds and the different people and organizations bearing them, such as animal holders, county, region, state or European Union, but it may also be due to the fact that economic analyses are both complex and time consuming. Only recently attention has turned towards economic analysis in animal disease control. Examples include situations, when decisions between different control measures must be taken, especially if alternatives to culling or compulsory vaccination are under discussion. To determine an optimal combination of control measures (strategy), a cost-benefit analysis should be performed. It is not necessary to take decisions only based on the financial impact, but it becomes possible to take economic aspects into account. To this end, the costs caused by the animal disease and the adopted control measures must be assessed. This article presents a brief overview of the methodological approaches used to retrospectively analyse the economic impact of two particular relevant diseases in Germany in the last few years: Bluetongue disease (BT) and Bovine Spongiform Encephalopathy (BSE).

Keywords: animal disease, animal health economics, cost-benefit analysis, bovine spongiform encephalopathy, BSE, bluetongue disease

Zusammenfassung

Obgleich die Bekämpfung von Tierseuchen eine lange Tradition hat, gibt es verhältnismäßig wenige Studien, die sich mit den daraus resultierenden Kosten beschäftigen. Das liegt vermutlich zum einen daran, dass die Kosten bei unterschiedlichen Trägern entstehen, wie Tierhalter, Landkreis, Bundesland, Staat oder EU, und zum anderen daran, dass ökonomische Analysen komplex und langwierig sind. In den letzten Jahren wurden Tierseuchenbekämpfungsmaßnahmen jedoch immer wieder kritisch hinterfragt, insbesondere indem Alternativen zu den ergriffenen Maßnahmen wie der Tötung oder Impfung in die Diskussion einbezogen wurden. Um festzustellen, welche Kombination von Maßnahmen der Tierseuchenbekämpfung („Strategie") am sinnvollsten ist, muss in der Regel eine Kosten-Nutzen-Analyse durchgeführt werden. Diese wiederum setzt eine Analyse der von der Tierseuche verursachten Kosten und der bisher ergriffenen Maßnahmen voraus. Dabei müssen Entscheidungen nicht ausschließlich nach Kostenaspekten getroffen werden, aber ihre Berücksichtigung wird ermöglicht. Dieser Artikel beinhaltet einen kurzen Überblick der methodischen Ansätze, die genutzt werden, um retrospektiv beispielhaft die ökonomischen Auswirkungen der Blauzungenkrankheit (BT) und der Bovinen Spongiformen Enzephalopathie (BSE) zu analysieren, zwei Tierseuchen, denen in Deutschland in den letzten Jahren eine erheblich Bedeutung beigemessen wurde.

Schlüsselwörter: Tierseuche, Tiergesundheitsökonomie, Kosten-Nutzen-Analyse, Bovine Spongiforme Enzephalopathie, Blauzungenkrankheit

Introduction

Successful control of infectious disease outbreaks depends on a series of strategic decisions concerning effective control measures, e. g. compulsory vaccination against Bluetongue disease (BT) or the feed ban and removal of specific risk material for Bovine Spongiform Encephalopathy (BSE). Regulatory decisions have to be taken under high time pressure and are increasingly exposed to public scrutiny especially due to their high impact on international trade but also for animal welfare concerns. However, only a small number of cost analyses or cost-benefit analyses are available in veterinary literature, and policy management on control strategies is seldom guided by solid economic arguments. For example, for the BSE control program in Germany, no economic analysis was carried out in advance. Decisions regarding the surveillance programs were rather obviously influenced, amongst others, by studies with extremely high mortality predictions as e. g. Ghani et al., who predicted up to 136,000 vCJD cases in Great Britain (Ghani et al., 2000). As a result, between 2000 and 2010, about 2 billion Euro were spend for control measures (Probst et al., 2013). Society and governments, however, get increasingly sensitive for economic issues (which is reflected in international projects like NEAT – Networking to enhance the use of economics in animal health education, research and policy-making in Europe and beyond) and animal disease contingency plans are evaluated also from an economic point of view.

Recently published studies (e. g. Häsler et al., 2012; Probst et al., 2013; Rushton, 2009; Velthuis et al., 2010;) show that economic analyses are complex and time consuming. They are also rather heterogeneous with regard to their terminology, the types of information sources and parameters used, data accuracy, applied methodology, level of analysis (farm, national or international) and the relevance of results. Many of these parameters depend on different factors, including animal species, type of disease and control measures, administrative structures of the veterinary services, payers and refund systems in different countries (Tab. 1). Therefore, the results can often not be compared with each other. Also, most studies are limited on the financial impact of the disease under consideration and do not include the benefit of control measures. In this article, we first explain some of the basic concepts in planning and performing an economic analysis, and then outline the methodological approach used in two retrospective analyses performed on country level (Germany) for BT and BSE.

Bluetongue virus serotype 8 (BTV-8) is a significant pathogen of ruminant livestock that was detected for the first time in Germany in August 2006. In 2006 and 2007 the disease spread over wide parts of western Germany and had a high economic impact on sheep and cattle farms. In May 2008, Germany started a vaccination program with inactivated vaccines. In 2008 and 2009, vaccination was compulsory for cattle, sheep and goats, after 2009 vaccination was voluntary. Since 15 February 2012, Germany is free from BT.

Bovine spongiform encephalopathy (BSE) is a chronic, degenerative disease affecting the central nervous system of cattle. The first case of BSE in an animal born and raised in Germany was detected in November 2000. Since then, a total of 413 BSE cases have been confirmed, the most recent one on 22 June 2009. Currently, according to the World Animal Health Organisation (OIE) Resolution No 18 of May 2014, Germany is recognized as having a controlled BSE risk status.

Basic concepts of an economic analysis

(I) Estimating the costs of a disease: Cost analysis

The **total costs** of a livestock disease (TC) are the sum of all direct costs (DC), precisely the loss of profitability of the production system, and indirect costs (IC), including the costs of controlling the disease. They can be described as follows:

(1) $TC = DC + IC$

Quantification of the loss of profitability is derived from the economic situation of a production system under "normal" circumstances and involves the estimated inputs and outputs of a farm. Inputs include both fixed and variable costs. Since fixed costs (e. g. property taxes) are long-term costs not influenced by a disease outbreak, they are not considered. **Variable costs** (VC) are all medium and short-term operating expenses that provide direct input to production like purchased feed, water, veterinary treatment, and other resources (insemination, replacement of old animals, etc.). On the other hand, **outputs** (O) include the revenues from sold goods and services like milk, wool, live animals, manure, or tourism. The difference between output (O) and variable costs (VC) is a measure of profitability of a farm and is called **gross margin** (GM). It can be described as follows:

(2) $GM = O - VC$

In case of an outbreak, **outputs** might decline (ΔO) and include both, visible (e. g. reduced fertility or milk yield, deaths, meat that cannot be sold) and invisible production losses (e. g. delay in the sale of animals). **Variable costs** usually vary as well (ΔVC) and may either increase, e. g. due to veterinary expenses and unused space, or decrease, e. g. due to reduced feed intake, or insemination costs.

TABLE 1: *Selected studies on animal health economics*

Type of analysis	Disease	Control strategy	Net benefit	Losses	Years	Study
Animal disease impact study	Classical Swine Fever	n. a.	n. a.	USD 2.3 billion	1997–1998	Meuwissen et al. (1999)
Animal disease impact study	Foot-and –Mouth Disease	n. a.	n. a.	GBP 8 billion	2001	Richard Eales (2002)
Animal disease impact study	Bluetongue disease	n. a.	n. a.	EUR 202 million	2006–2007	Velthuis et al. (2010)
Animal disease impact study	Bovine Spongiforme Encephalopathy	n. a.	n. a.	EUR 2 billion	2001–2010	Probst et al. (2013)
Cost-Benefit analysis	Salmonellosis	Four strategies	EUR -262.3 to 3.5 million		2005–2020	Goldbach and Alban (2006)
Cost-Benefit analysis	Bluetongue disease	Three strategies	CHF 17.5 million		2008–2011	Hasler et al. (2012)

n. a. = not applicable

The difference between the gross margins of a farm under "normal" circumstances (GM_N), i. e. in absence of a disease, and under the influence of a disease outbreak (GM_D) gives us the **direct costs** (DC) on the farm level, which we then can extrapolate for the entire population. Direct costs include the difference (usually reduction) of farm outputs (ΔO) and the difference of variable costs (ΔVC) due to the disease itself. **Direct** costs are generally borne by the farmers and can be described as follows:

(3) $DC = \Delta O + \Delta VC$

Variable costs might either increase, e. g. due to treatment of infected animals (**T**) or expenditures on other (non-veterinary) resources (**R**) (e. g. lower feed conversion of the animals), or diminish, e. g. in terms of otherwise resulting costs (e. g. reduced feed intake) (**B** for "benefit" due to the disease). Hence, direct costs on farm level can be described more precisely as follows:

(4) $DC = \Delta O + \Delta\ (T + R - B)$

The second component needed to calculate the total costs is composed of the **indirect costs** (IC). Indirect costs usually accrue to the region or federal state, the country or the EU and include the costs of all measures taken to prevent, diagnose and control the disease on both farm level (e. g. vaccination, insecticide treatment) and population level (e. g. epidemiological investigations, culling, monitoring/surveillance, removal of specified risk material). They also include the economic impact on national markets, e. g. due to export bans, changed consumer behaviour, cheaper prices for animal products, increased need for research, or reduced tourism (Dijkhuizen and Morris 2002, Rushton et al. 1999). To estimate indirect costs, all these factors are added up, for example:

(5) $IC = M + A + S + E + RS + K$

where **M** stands for control measures, **A** for administrative costs, **S** for monitoring/ surveillance, **E** for export, **RS** for research and **K** for the effects on the market.

(II) Estimating the benefit of control measures: cost-benefit analysis

Cost analyses can help to determine which factors have the greatest impact on the total costs. However, they are not suitable for weighing costs against expected benefits of control measures, or in choosing between different control strategies. For this purpose, the cost-benefit analysis is the method of choice. **Benefits** include a situation where there are less infected animals than in absence of the implementation of a disease control strategy, thereby leading to reduced losses in income, reduced costs for treatment etc., which are usually more difficult to quantify than (actually incurred) costs. Relating both direct and indirect costs of the disease with the benefits of the control measures yields the total economic impact of the disease.

In a cost-benefit analysis, the **Net Benefit** (NB) describes the difference between costs and benefit between two strategies. For example if the standard strategy is without vaccination and the alternative strategy includes vaccination, the difference in the **Benefits** (B) can be the difference in losses between both strategies (e. g. reduction in infected animals, a reduction of losses in income and lower costs for treatment). On the other hand, the vaccination strategy causes additional **Costs** (C) for vaccines and for vaccinating the animals. A cost-benefit analysis can be described by the following formula

(6) $NB = \Sigma^{t}_{t=0}\ B_t - C_t$,

where NB stands for Net Benefit, B for the difference in the Benefit, C for difference in the Costs and t for time (years).

If control programs are running over a long time (e. g. BSE), the costs and benefits need to be corrected by inflation and interests. In control programs running for more than one year, the costs and benefits have to be calculated for all years

Material and Methods

For our two examples, first, we collected epidemiologically relevant and economic data from different sources, including the German Federal Ministry of Food and Agriculture, the Federal Statistical Office (Destatis), official reports, and scientific publications. Due to the decentralized structure of Germany, the main information sources were the Federal States, the animal health services, the animal compensation funds (Tierseuchenkassen), the German animal disease notification system (TSN), and the central animal movement database (HI-Tier). All collected data were included in a standard spreadsheet (Microsoft Excel 2010). If data were incomplete or uncertain, we had to use empirical distributions if data existed or to model distributions (uniform, triangular), if only expert opinion were available. These distributions were used in a stochastic simulation model (@Risk 5.7, Palisade Corporation, Ithaca, New York, USA).

Regarding BT, both direct and indirect costs were estimated for a time period of six years. Regarding BSE, we focused on the costs incurred by the measures to control the disease and to prevent exposure of consumers to the causative agent over a time period of ten years.

Example 1: Bluetongue disease

The costs for Bluetongue were analysed for the period between 2006 and 2011. In a first step, a gross margin analysis was carried out to estimate the direct costs of the disease on farm level for different species (cattle and sheep), production types (dairy or meat) and – for dairy farms only – years. The herd level model was based on an analysis of affected farms in North Rhine-Westphalia. As the milk price changed over the years, we had to analyse the costs for an affected animal for all analysed years. In sheep, the variability of the meat price was low, hence we used only one estimate. The result was a distribution of the direct costs on animal level.

For modelling costs on country level, we estimated the number of clinically affected animals in the population and multiplied it with the direct costs on the animal level.

For the indirect costs, we included the following cost factors in the analysis: Bluetongue surveillance (S), additional testing for export (E), control measures (M), and administrative costs (A).

$$(7)\ TC_{BT} = \sum_{y=2006}^{2011} DC_y + \sum_{y=2006}^{2011} (S_y + M_y + E_y + A_y)$$

Surveillance included a cross-sectional study, an active surveillance system (sentinel surveillance and annual surveillance to demonstrate freedom from disease) and vector monitoring. The **control measures** included treatment with insecticides and vaccination. The **administrative costs** included epidemiological investigations, disease confirmation (farm visits) as well as the establishment of restriction zones and additional time to enter information on new outbreaks into the databases.

To estimate the additional export costs, we used the number of cattle and sheep exported and multiplied it with the costs for the test to confirm that an animal was free from bluetongue disease. As the disease had started in August 2006 in the western part of Germany and had not affected the whole country until October 2007, we estimated the fraction of animals that was affected by export restrictions in both years, 2006 and 2007.

Example 2: Bovine Spongiform Encephalopathy

The costs incurred in Germany by the legal provisions to control BSE from November 2000 to 2010 were estimated by means of a stochastic model (Probst et al., 2013). The following five cost factors were included in the analysis: **active BSE surveillance** (S), response **measures** adopted at the **slaughterhouse** (Ms) and the **farm of origin** (Mf) following confirmation of BSE, **removal of specified risk material** from cattle (SRM), extension of the **feed ban** on animal proteins (F), and **disposal of category 1 material** (I). To determine the total costs BSE, the following basic equation was used:

$$(8)\ TC_{BSE} = \sum_{y=2000}^{2010} (Ms_y + Mf_y) + \sum_{y=2001}^{2010} (S_y + SRM_y + F_y + I_y)$$

Concerning BSE **surveillance**, we differentiated between compulsory surveillance as stipulated by EU legislation, compulsory surveillance in accordance with national German regulations (beyond EU legislation) and voluntary testing. We also differentiated between cattle slaughtered for human consumption and fallen stock (risk cattle).

With regard to the response measures at the **slaughterhouse**, we took into account the value of the carcasses that were destroyed after the detection of a BSE case in routinely slaughtered cattle. The response measures on the **farm of origin** include the labour costs for undertaking epidemiological investigations and the costs for cohort culling.

The recurrent costs for the **safe removal of SRM** from slaughter cattle were calculated by multiplying the number of slaughtered cattle with the costs per animal. Since the list of SRM depended on the age of the animal, we differentiated between three different age categories, i. e. animals of < 12 months, 12–24 months, and > 24 months of age.

Regarding the costs of the **extension of the feed ba**n, we took into account the costs for the destruction of all stocks of animal protein and feed containing it, the lost revenues from the sale of animal protein to the feed industry, the additional costs of substituting animal protein with soybeans in livestock feed, and the official tests to control the feed ban.

The costs for the **incineration of animal protein** were estimated by multiplying the amount of protein incinerated with the average admission fee that had to be paid for incineration.

Results

Example 1: Bluetongue disease (BT)

The total costs caused by BTV-8 for the years 2006–2011 were estimated at 200 million Euros, with a maximum of 87 million Euros in 2007. In 2006 and 2007, the highest costs were induced by production losses and fallen stock, while between 2008 and 2010, the highest costs were induced by vaccination.

Example 2: Bovine Spongiform Encephalopathy (BSE)

The total costs of BSE were estimated to range between 1 847 and 2 094 million Euros. More than half of the costs (approximately 1000 million Euros) were incurred by the extension of the feed ban for animal protein to all farmed livestock. Active surveillance accounted for 21% (405 million Euros), the incineration of animal protein for 13% (249 million Euros) and the removal of specified risk material for 11% (225 million Euros). Only 1% of the costs were related to response measures after detecting a BSE-positive animal, including indemnity payments for culled cattle and confiscated carcasses at the slaughterhouse.

Discussion

Cost analyses of animal diseases follow a multidisciplinary approach and include animal production, product processing, veterinary, epidemiological and economic expertise. In both examples presented in this article, BT and BSE, the most time-consuming step was collecting data and preparing them for analysis. Probably, this holds true for most economic studies. In both studies, the total costs widely depended on some variables that were estimated with a high level of uncertainty (e. g. costs of substituting animal protein with soybeans). This shows that after performing an economic analysis, quantifying its reliability, e. g. by means of a sensitivity analysis, is of utmost importance. Concerning BT, the estimated morbidity had the biggest influence on the outcome of the model. For the costs of BSE, sensitivity analysis showed that the admission fee for animal proteins at the incineration plant had the strongest impact.

In both studies, the direct and indirect costs as well as the benefits of control measures turned out to be interdependent. They influenced each other in different ways. In the example of BT, short-term costs for having animals treated by a veterinarian may discourage farmers to treat their animals. On the other hand, if the animals are not treated, the farmer may save money in the short-term, but the farm output could be substantially lowered in the long run. In the case of BSE, decreased consumption and prices of beef may have resulted in an increased consumption and prices of other types of meat, milk products or vegetables. These examples show how important it is to take potential temporal effects on the economic analysis sufficiently into account.

In both studies, total costs varied considerably across regions and from year to year. Depending on the type of costs, they are borne by different stakeholders, precisely by farmers, the industry and the public. Regarding bluetongue disease, (mainly direct) costs were borne by the farmers between 2006 and 2007, whereas the main costs (vaccination) were covered by the animal disease compensation funds in the years 2008 and 2009. Concerning BSE, the costs were borne by farmers, processors, consumers, the German government and the federal states. Sometimes the cost distribution was not obvious and difficult to assign precisely to the different contributors, especially when it came to indirect reimbursements or distortions on the animal production value chain, e. g. due to reduced meat consumption or reduced beef prices.

Both studies also show the large impact of the disease, but also of the control measures on domestic and international markets. Disease outbreaks and the necessary measures to manage and control them may change the profitability of the whole production chain. To adopt effective control strategies for controlling a disease in livestock animals remains a major challenge, if the whole range of direct and indirect cost factors of both the disease and the control measures is taken into account.

Due to the paucity of comparable data, potential bias and the high complexity of influencing factors, especially in the case of BSE, it is difficult if not impossible to compare them with other studies (Tab. 1). Like most other recently published cost analyses, both studies have been performed retrospectively, i. e. years after the decisions on the control strategies had been taken:

Regarding BT, serotype 8, the member states of the European Union decided to carry out a compulsory vaccination program in 2008 without performing a cost-benefit-analysis beforehand. Although the vaccination program was successful in controlling the disease, retrospective analysis showed that it had been very expensive. The same applies to BSE: the control measures in their entity were successful in combating the disease and in preventing exposure of consumers. However, most if not all decisions on the control of the disease on the level of legislation were adopted without taking economic considerations into account. Of course, this approach was influenced by the anticipated impact of BSE on human health, i.e. the emergence of an epidemic of variant Creutzfeldt-Jakob disease in the human population.

To provide decision makers with solid economic arguments before a control strategy is implemented, costs (and benefits) of a disease and control measures should be anticipated in a prospective cost-benefit analysis, if possible. The major challenge of a prospective analysis relates to estimating what could occur in the case of a disease outbreak and in the presence or absence of different alternative control measures. Therefore, high-quality data on various levels of the feed and food production chain need to be compiled and constantly updated, even before a disease outbreak occurs.

Conflict of interest

The authors declare no conflict of interest.

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