Basic framework for the economic evaluation of animal health control programmes

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Summary: The further integration of international markets means that co-ordinated policies against contagious animal infections have become increasingly important, and stricter demands for control and eradication should be expected in the future. To meet these demands, it would be desirable to create a computer simulation environment in which 'what if?' scenarios could be performed, in order to explore the epidemiological and economic effects of various infections and control strategies.

The authors propose a flexible economic framework and illustrate this framework with an example. The framework has four elements: changes in the percentage of infectious herds, changes in product quantities, changes in product prices and economic integration. Each element is specifically defined and has its own input and output data, depending on the control strategy under consideration.

In an illustration of the framework, probability distributions of the different control strategies are compared and the optimal strategy is chosen, according to the attitude of the decision-maker towards risk. Such a framework can be considered as a new standardised approach for comparing and selecting animal health control strategies, by integrating technical and economic data and principles.


INTRODUCTION

The further integration of international markets means that a co-ordinated policy in the control and eradication of contagious animal infections has become increasingly important. Moreover, profit margins in modern livestock farming are typically small in relation to the resources committed to production. Therefore, control of production costs is also becoming increasingly important (26, 40). Improving animal health is a

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key feature of this control and in recent years this aim has been achieved through prevention programmes, on the principle that ‘prevention is better than cure’ (44).

The application of such programmes is rarely definitive. Usually, several programmes are available, each offering a different degree of protection. To determine the most favourable programme in economic terms, several effects, epidemiological as well as economic, must be taken into account. The optimal programme is determined according to the equimarginal principle (18, 43). This principle states that the use of any input should be increased up to the point at which the cost of an additional input equals the return from that additional output. However, policy decisions on animal health control have to be taken with imperfect knowledge. That is why a computer simulation environment, in which ‘what if?’ scenarios could be performed, would be desirable. Such a model would enable one to explore the epidemiological and economic effects of various infections and control strategies (which are characterised by uncertainty) simultaneously (15). The objective of this study is to propose a standardised framework integrating the most important components of animal health control, and the relationship between these components. Although the economic effects of different levels of infections have already been explored in the literature (17, 23, 39), a wide range of approaches is used, making comparison of the outcomes difficult. Therefore, the main goal of the approach proposed in this article is to devise a standard framework, capable of incorporating key components and relationships in an appropriate amount of detail.

First, several basic underlying economic principles are described; in particular, the nature of the decision-making process, the valuation of costs and benefits, and the approaches used in economic analysis. Secondly, the basic conceptual framework of animal health control is presented. Special attention is paid to four principal elements: changes in the percentage of infectious herds, changes in quantities produced, changes in product prices and the integrated economic model. This approach is illustrated by an example.

**BASIC ECONOMIC PRINCIPLES**

**The decision-making process**

The decision-making process is commonly considered to have five stages (10):

1. recognising the problem
2. developing solutions
3. choosing a solution
4. implementing the decision
5. evaluating the results.

Current infection information systems focus mainly on stages 1 and 2 (45). Most systems include historical data, which are used retrospectively to detect and solve problems (42). These systems will become more attractive when modelling tools are included to assist in choosing a solution (stage 3), and in evaluating the results (stage 5). In all cases, the decision-maker and not the system is responsible for the final decision (1).
Valuation of costs and benefits

Policy decisions in animal health control are taken and implemented at different economic levels: the herd level (17), the regional level (42), and the national and international levels (9, 23). This study proposes a framework to evaluate control programmes at the regional and national levels. The value of a control programme can only be determined in relation to the value of an alternative programme. The economic ‘cost’ of resources used in any programme in fact represents the potential returns that could be gained by employing those same resources in the best possible alternative programme. Such costs are called the ‘opportunity costs’ (29). Similarly, the revenues of any control programme represent the extra earnings gained when such a programme is implemented, in comparison to what would happen if the programme were not implemented (52). Specific problems in the calculation of costs and benefits are as follows (20, 33):

- determining the types and categories of costs and benefits to be included in the analysis
- choosing the appropriate prices for these categories
- choosing an appropriate discount rate to account for time preference of money.

In general, there are two methods for measuring costs and benefits. In mathematical terms, these two methods are integral calculation and differential calculation. The former calculates total costs and benefits, the latter calculates only the changes in costs and benefits (50). In the case of policy decisions in animal health control, most of the factors involved in applying different strategies are incremental, and thus differential calculation is the more appropriate technique. Only those factors which change must be included. This method has been used in studies by Berentsen et al. (8), Houben et al. (23), Hugoson and Wold-Troell (24), Van der Kamp et al. (53) and McInerney and Turner (36). In these studies, only changes resulting from a certain control programme were measured and evaluated.

Market prices are not always available or do not always reflect the true economic values of products to society. For instance, market prices do not account for such external aspects as effluent pollution of a water course or loss of amenities due to an intensive pig-farming installation. An economic value is the value associated with one unit of a product, which indicates how much the welfare of society can be improved (or worsened) by the use (or loss) of a marginal unit of that product. When market values are unavailable or inappropriate, then implicit marginal values must be assigned. Such values are called ‘shadow prices’ (49).

Another common problem is caused by differences in the time periods over which costs and returns are distributed. The value of money (or, more strictly, of the real goods which money buys) varies over time (time preference). Therefore, a discount factor must be used to ensure that costs and returns distributed through time are comparable at a given point (52). Moreover, inflation reduces the purchasing power of money, and so the social discount factor is generally calculated by subtracting the inflation rate from the market interest rate for real estate. The resulting discount rate is assumed to reflect time preference accurately (49).

Economic analysis

There are two approaches to economic analysis: the positive (empirical) approach and the normative (deductive) approach (27). Both methods are useful, and are
complementary in supporting policy decisions for animal health control. The positive approach observes the actual effects of infection. This approach is complicated by the fact that many relevant variables are difficult, if not impossible, to quantify. For example, infection data are also influenced by highly variable and often intangible factors, such as climate and management. Such considerations may mean that an appropriate set of empirical data is not available for analysis at the point at which a policy decision must be taken. It appears that several studies have used empirical data to support policy decisions in animal health control (24, 35, 36, 47). Usually, a single-point outcome is obtained, which must be interpreted for a wider range of possible circumstances which characterise the various control programmes. Gathering empirical or observational data for any specific case may also be very costly and time-consuming.

The normative or deductive approach predicts effects by constructing a theoretical model of the infection (23). This approach includes mathematical models to solve either optimisation or simulation problems. Optimisation tries to find the best solution in terms of the function and restrictions of the objective. By contrast, simulation is an attempt to imitate real-life conditions, which may not be consistent with the criteria of economists for optimisation. That is, a simulation model provides answers to "what if?" questions. To support policy-making in animal health control, a wide range of possible components and frequency distributions can be calculated for both data and the various outcomes of control programmes (25, 31). The validity of the simulation model must be carefully established, to have confidence in the conclusions. The validity of an optimisation model depends on the optimising assumption (of, for example, linear programming) being consistent with the realities of the problem under analysis. However, extra attention must be given to the validation of simulation models. Simulation is such a broad and flexible modelling approach that the assumptions are essentially specific to the problem. In many cases, such assumptions are implicit in the model and are never explicitly specified (12).

Epidemics and changes in prices are dynamic and stochastic (i.e. governed by the laws of probability) in nature, and therefore subject to uncertainty, both in the exact form of the dynamic relationships and in the way epidemics and price changes are influenced by external factors (22, 34, 38, 40). Therefore, a dynamic stochastic simulation model is preferred over a deterministic model to support policy-making in animal health control.

CONCEPTUAL FRAMEWORK

The factors to be considered in the economic evaluation of policy decisions in animal health control form part of the conceptual framework (Fig. 1).

As shown by this figure, the framework can be subdivided into four elements:

- changes in the percentage of infectious herds
- changes in quantities of products
- changes in prices of products
- an integrated economic model.
The basic conceptual framework for policy decisions in animal health control

These four elements each have their own inputs. Examples of such inputs include the following:
- the structure of the production sector affected by the infection
- the number of animal contacts between herds
- herd density
- the number of export markets.

Depending on the control strategy, each element provides an output. Examples of such outputs are the percentage of infectious herds over time and the expected total costs (with variation) of the control strategy. Vaccination or culling infectious herds are examples of control strategies.

In the following sections, the four elements of the conceptual framework are described in detail and translated into a quantitative model. To illustrate this process, a continuing example is provided.

Example – introduction and assumptions

In this illustration, a vaccination strategy (Strategy 1) is compared with a situation in which no vaccination takes place (Strategy 2). Before the simulation starts, a number of conditions and parameters must be provided. At the beginning (time \( t = 0 \)), approximately 25% of herds are affected by a particular viral infection. This infection affects the production of two complementary products, i.e. live hogs (A) and pork (B) on the Dutch market. Products A and B are both sold on the domestic market (DM). Product A is also sold on two export markets (EM1 and EM2). A week is used as time step \( t \) (0 \( \leq t \leq T \), with \( T = 190 \) weeks).

Suppose that the following important events occur:

For Strategies 1 and 2:
- \( t = 20 \) the first steps in closing export market 1 (EM1) are taken, due to the occurrence of the infection
- \( t = 30 \) export market 1 is completely closed.
For Strategy 1 only:

- \( t = 45 \) the control strategy is applied
- \( t = 120 \) the infection is totally eradicated
- \( t = 125 \) export market 1 (EM1) is reopened, due to the complete eradication of the infection.

These conditions and parameters continue to be used below.

**Elements of the framework**

*Changes in the percentage of infectious herds (\( \Delta I \))*

In general, the evolution of an infection (e.g. the change in the percentage of infectious herds) over time is a function of two factors:

- the distribution of the agents (viruses or bacteria) which start infection
- the susceptibility of the population in which the agent appears.

Both features are influenced by characteristics of the infection agents and the environment. For example, an infection agent may spread infection by air (airborne transmission) or by vectors, and – depending on the specific circumstances – herd density, herd type and different contacts between herds or individual animals become significant in this process (41, 48). Such contacts, or routes of transmission, can be subdivided into direct contact, transmission on fomites, airborne transmission, indirect transmission through other species, and minor disease-specific routes, such as venereal or iatrogenic transmission.

Such characteristics of the infection and the environment, together with the level (animal, herd, regional or national) at which the policy decision is to be taken, determine how the infection can be analysed or simulated. To simulate an infection, a state-transition approach can be used and the above-mentioned features taken into account (4, 7, 23, 28). In the models given in this paper, the population is divided into a limited number of states which take the different infection agents and environmental characteristics into account. The modelling begins with the allocation of the modelling units (herds) to different states. The simulation of the infection can then be commenced.

To determine whether a control strategy is effective, the spread of the infection is evaluated. The basic reproduction ratio (\( R \)) is used in various studies for this purpose (23, 28). \( R \) is defined as the number of secondary cases resulting from a single infectious herd. When \( R < 1 \), the infection will spread in such a way that it eventually dies out. When \( R \geq 1 \), the infection will not die out.

*Example (continued) – changes in the percentage of infectious herds*

At time period \( t \), each herd in the population is in one of three states (\( p \)) as follows:

- infectious
- not infectious and not immune
- immune.

Infectious and/or infected herds are assumed to be in the infectious state. The spread of the infection is represented by the transmission rate (\( TR \)), which is defined as the
average number of herds to which the virus is transferred by each infectious herd, irrespective of the status of the recipient herd. Differences in susceptibility (immune and not immune) are included by the within-herd susceptibility (WHS). The fraction of herds that becomes infectious at time $t$ ($pi_{p,t}$) is as follows:

$$pi_{p,t} = WHS_p \times (1 - e^{-TR \times f_{t-1}})$$

$pi_{p,t}$ is the probability of a herd in the non-infectious state $p$ (not infectious and not immune, and immune) becoming infected in week $t$, $WHS_p$ is the within-herd susceptibility for a herd in the non-infectious state $p$ and $f_{t-1}$ is the fraction of herds infected during the previous time period (week).

To include stochasticity, a random number from a uniform distribution is used to calculate the number of non-infectious herds which will become infectious during each time period ($t$). At the same time, the number of infectious herds which will become non-infectious is calculated by using transition values of a transition matrix (2, 3, 28). The values for TR, WHS, the transition matrix and the starting distribution are described in Appendix I.

Results from this method are shown in Figure 2. In this figure, the percentage of infectious herds per time period is given for each control strategy (Strategy 1 being vaccination and Strategy 2 being no vaccination).

Before $t = 45$, no vaccination was used in either strategy and $R = 8.75$, which means that the infection would not die out unless a control programme were initiated. This situation results in a steady state distribution of almost 25% of herds becoming

![Graph showing percentage of infectious herds over time (0 ≤ t ≤ 190) for control strategies 1 and 2](image-url)

**FIG. 2**

Percentage of infectious herds over time (0 ≤ t ≤ 190) for control strategies 1 and 2
infected. After the start of the control programme \((t = 45)\), the percentage of infectious herds remains steady for Strategy 2 and, initially, decreases rapidly for Strategy 1. This decrease is followed by a less rapid decrease after \(t = 55\), and total eradication is achieved at \(t = 120\). It could be deduced that the infection would eventually be eradicated in Strategy 1 from \(R\), which was 0.89 when eradication measures were included. Based on this information only, Strategy 1 would be preferred to Strategy 2 because it eradicates the infection.

**Changes in quantities of products (\(\Delta Q\))**

Changes in quantities of the affected products per production unit must be determined by analysis of empirical data, by searching the literature or estimates by experts. Production data and data concerning the infection are frequently recorded but seldom linked. This means that data on the consequences of the infection are rarely complete.

Direct consequences of changes in the progress of the infection may be divided into the following:

- additional outputs realised from a certain change (i.e. the implementation of a control programme)
- reduced inputs as a result of a change
- reduced outputs as a result of a change
- extra inputs incurred by the implementation of a change.

For example, infected animals frequently consume less feed. In other words, the use of an input is reduced. By contrast, infected animals need more veterinary services and labour which represent additional inputs.

In terms of output, the amount and quality of milk, meat, wool, manure, or draught power will be unchanged or decreased. Of course, the nature of the affected products depends on which production sector has been directly affected by the infection. In addition to any possible direct effects on the final product, the infection may also influence the production of intermediate products (e.g. piglets or pullets) and will, in time, influence the total value of the production sector (including exports).

Figure 3 summarises the principal herd types and subsectors in meat production (pigs, beef or poultry). If, for example, an infection affects the production of piglets in breeding herds, the supply of piglets to fattening herds decreases correspondingly, which, in turn, later results in a decrease in the supply of fattened pigs to the slaughterhouse.

In addition to the direct consequences within a production sector, the infection may also affect other production sectors (8). For example, an infection-induced fall in the supply of pork on a market increases its price, which causes an increased demand for chicken on the same market.

*Example (continued) – changes in quantities of products*

Given the percentage of infectious herds (calculated in the previous stage of the model), the resulting changes in quantities of products (\(A\) and \(B\)) can be determined. The infection is assumed to cause a 5% production loss in product \(A\) and a 10% production loss in product \(B\) per infectious herd. It should be remembered that, due
to the infection, export market EM1 begins to close its borders for product A at 
t = 20 and the market is completely closed at t = 30. After total eradication of the 
infection at t = 120 (Fig. 2), export market EM1 begins to reopen its borders at 
t = 125 if Strategy 1 is used. The border remains closed if Strategy 2 is used.

The general principle is that each product has a supply and demand function, which 
includes supply and demand on both domestic and foreign markets and factors which 
fluence supply and demand (i.e. infections). If there is no stock of products, or a 
constant stock, changes in demand for those products are the same as the changes in 
supply. If one also assumes that the difference in price of a product on two different 
markets is caused by transportation costs and tariffs on international trade, the 
quantities and prices of the products on the different markets can be calculated.

Figure 4 shows the total production of products A and B.

After the borders of EM1 have been closed, the amount of product A which is 
available to the domestic market and to EM2 is increased. The technique used to 
calculate the distribution among the different markets is described in the section below 
entitled 'Changes in product prices'. At t = 45, vaccination is begun in Strategy 1, 
which results in an increase of products A and B. After the total eradication of the 
infection (t = 120), the total production of both product A and product B increases in 
the case of Strategy 1. Production of A increases by 1,600 units (from 148,200 to 
149,800), while production of B increases by 4,300 units (from 175,700 to 180,000). 
However, if Strategy 2 is employed, production remains the same (Fig. 4).

Changes in product prices (ΔP)

After the changes in quantities of products have been estimated, the resulting 
changes in prices must be calculated. Each change in production may have a direct 
influence on both the price of the product concerned and, indirectly, on the prices of 
other closely related products on the same market. For example, a change in the 
number of piglets produced will have a direct influence on the prices of such piglets, 
and an indirect influence on the prices of fattened pigs. Moreover, the same product 
can be distributed on different markets (e.g. export). The proportions in which the 
products are distributed among these markets may change over time because of the 
prices of these products, prices of complementary or competitive products, and/or 
other external factors within these markets (e.g. government policies such as export 
bans).
In a study by Houben et al. (23), fixed prices were used, whereas the export model described by Berentsen et al. took into account direct as well as indirect ways (e.g. export bans) in which prices of products were affected by changes in the quantity of those products (8). Market equilibrium models are used in our approach (5, 21, 54), because such models also incorporate cross effects of prices of other products on different markets (see the section above entitled ‘Changes in quantities of products’). This method is not yet used to support policy decision-making in animal health control.

Example (continued) – changes in product prices

The quantity of product A demanded \((Q_A^D)\) can be divided into the demand on the domestic market \((Q_{A,DM}^D)\) and the export markets \((Q_{A,EM1}^D, Q_{A,EM2}^D)\).

\[
Q_A^D = Q_{A,DM}^D + Q_{A,EM1}^D + Q_{A,EM2}^D
\]

2

The quantity of product A demanded by the domestic market \((Q_{A,DM}^D)\) is influenced by the price of that product \((p_{A,DM}^D)\) and the price of product B \((p_{B,DM}^D)\).

\[
Q_{A,DM}^D = a_{A,DM}^D + b_{A,DM}^D p_A + a_{A,B}^{DM} p_{B,DM}^D
\]

3
The factors a and b are fixed parameters which can be calculated from data by using simultaneous equation estimation methods.

Products A and B are complementary products, which means that, without any market disturbance, the demand for one product will move in the same direction (but not necessarily by the same amount) as the demand for the other product.

The quantity of product A demanded on the export markets \( Q_A^{D,EM_i} \) where \( i = 1 \) or 2 is influenced by the prices of product A on these markets \( p_A^{EM_i} \).

\[
Q_A^{D,EM_i} = a_A^{EM_i} + b_A^{EM_i} p_A^{EM_i}
\]

However, the prices of product A on export markets \( p_A^{EM_i} \) are also related to the price of product A on the domestic market \( p_A^{DM} \) because, as mentioned earlier, prices of the same product in two different countries can differ only as a result of transportation costs (T) and the effects of government policies, such as tariffs (G).

The quantity of product B demanded \( Q_B^{D,DM} \) is influenced by the price of product B \( p_B^{DM} \) and by the prices of product A on the domestic market \( p_A^{DM} \) and the two export markets \( p_A^{EM_i} \), in the same way as the quantity of product A is influenced in equations 2, 3 and 4. The prices of products A and B can now be calculated by solving the above system of equations (Fig. 5).

![Graph showing prices of products A and B over time under control strategies 1 and 2](image)

**FIG. 5**

Prices of products A and B over time under control strategies 1 and 2
Because transportation costs and tariffs remain constant during simulation, the difference between prices on the domestic market and on the export market is also constant. That is why Figure 5 shows only the price of product A on the domestic market. The price of product A decreases after EM1 has been closed (t = 20) under both strategies, because of the sharp increase in supply on the other two markets (DM and EM2). The price decreases further after Strategy 1 begins (t = 45), because of the increase in production of both products A and B. The price increases again after EM1 is reopened (t = 125). What is remarkable is the way in which these prices decrease and increase. This is caused principally by the assumption of no stock in this example, and by the relatively short period of time between closing and reopening the export market.

After EM1 begins to close (t = 20), the supply of product A increases on the domestic market (DM), as does demand because the price has fallen. Product B is complementary to product A, and thus the demand for product B also increases but the supply remains the same. This results in a price increase for B, which is shown in Figure 5. The implementation of Strategy 1 (t = 45) results in an increase in the supply of product B — which, in turn, results in a decrease in the price. After EM1 reopens (t = 125), the price of product B increases but remains lower than before the closure of export market EM1.

**Integrated economic model**

After the variations in quantities and prices of the different products have been calculated over time for each control strategy, these different strategies must be compared. In the literature, partial budgeting and cost-benefit analysis are commonly used to compare different control or prevention strategies (6, 13, 14, 22, 24, 32, 46, 47, 49, 51, 53). In addition to the comparison of different control strategies, a sensitivity analysis should be conducted to determine how variations in the magnitude of different parameters affect outcomes. Such an analysis provides a better insight into the relative importance of the different parameters for decision-making. A sensitivity analysis is performed by changing values of (uncertain) parameters and restarting the simulation. As soon as the most influential parameters in determining outcomes are identified, particular attention should be paid to ensure that realistic values are obtained for these parameters.

In general, decision-makers will react in a risk-averse way, fearing the personal consequences of having made an incorrect decision. The uncertainties associated with control programmes, however, are often small in comparison with the uncertainties associated with the behaviour of the whole economy. Therefore, a decision-maker should normally use risk-neutral rules, such as the expected monetary values of the different strategies. However, non-neutral rules should be considered if consequences of control programmes are not evenly spread among the population (16, 19). Stochastic dominance is a promising approach in helping to choose among options under such circumstances, but requires some information about the preferences of the decision-makers in regard to outcomes (1, 30).

**Example (continued) — integrated economic model**

At this stage, the net present value of production over time must be determined by using the calculated prices and quantities of products, costs per vaccination, etc. As
shown in Figure 6, the net present value of Strategy 1 is lower than the net present value of Strategy 2 after the strategies are implemented \((t = 45)\). This means that in this case, and in contrast to the conclusion based only on the changes in infection, no eradication seems to be economically preferable to eradication. This outcome results mainly from the costs incurred by vaccination, combined with the lower price of product A after eradication.

**FIG. 6**

Net present value of production over time under control strategies 1 and 2

When the economic results for each control strategy are derived from several simulation runs, a probability distribution of net present value can be calculated. Figure 7 shows the distributions for control strategies 1 and 2.

Strategy 1 gives the lower expected net present value \((E[1])\) with a small standard deviation, whereas Strategy 2 gives a higher expected net present value \((E[2])\) but with a larger standard deviation. The evaluation of the different control strategies involves a profit-risk trade-off. The outcome of this evaluation will depend on the attitude of the decision-maker towards risk. A risk-neutral decision-maker would opt for Strategy 2, whereas a risk-averse decision-maker may prefer Strategy 1 because of its smaller variation (i.e. less risk), which results in a lower probability of ‘bad’ net present values.

**DISCUSSION AND OUTLOOK**

This article proposes a standardised approach, which integrates the technical and economic data considered to be important in support of policy-making for animal health control. Most of these aspects have already been described in the literature, but
Probability distribution of net present value for control strategies, where E(1) and E(2) are the expected net present values for Strategy 1 and Strategy 2, respectively.

As shown in the example, the infection represents a dynamic stochastic process. The closure and reopening of an export market is also a dynamic stochastic process. Therefore, the choice of a dynamic stochastic simulation as a method of analysing this series of problems seems to be appropriate.

To model the infection, herds/animals in the example are divided into only three states. To be more realistic, more states should be defined. The number of states depends on the knowledge available about the infection and the amount of detail contained in other parts of the model or related to the nature of the infectious agent.
Between-herd spread of the infection is difficult to model, mainly because of a lack of empirical data about the course and extent of infection as it spreads from one herd to another. Between-herd spread is primarily a function of the following:
- the different ways in which contacts between herds occur
- prevalence of the infection
- possible carrier states
- herd density.

Contacts between herds can be subdivided into the following:
- direct contact
- transmission on fomites
- airborne transmission
- indirect transmission through other species
- minor disease-specific routes such as venereal or iatrogenic transmission.

It is possible to calculate the average number of animal contacts by analysing the frequency of animal movements in the entire production chain. To gain more insight into the impact of these contacts on the total between-herd spread, a sensitivity analysis of the relevant parameters should be conducted.

Another difficulty in modelling is estimating to what extent, and in what ways, product prices are influenced by, for example, changes in product quantities, prices of other products and external factors. This is particularly the case when the total market (supply and demand) is disturbed by the infection. In that case, too, a sensitivity analysis to identify the most influential parameters might provide a better insight into the relative importance of such factors.

In support for decision-making, it is desirable to present the various criteria by which the decision could be made, especially when these criteria would lead to different ranking of the control strategies (also illustrated by the example). This allows the decision-maker to choose the most appropriate criterion, taking into account risk preferences and attitudes. Whether an infection is highly contagious or slow to spread, and whatever the particular circumstances of the disease, the framework set out in this paper can be used to support policy-making in animal health control.

* * *


**Résumé:** Avec le progrès de l’intégration des marchés internationaux, la coordination des politiques contre les maladies infectieuses des animaux devient de plus en plus importante et il faut s’attendre à un renforcement à l’avenir des exigences en matière de prophylaxie et d’éradication de ces maladies. Pour répondre à ces exigences, il conviendrait d’élaborer des simulations informatiques permettant de mettre en œuvre des scénarios du type « Quid si ? » en vue d’examiner l’impact épidémio-logique et économique de plusieurs maladies et des stratégies de prophylaxie envisageables.

Dans l’exemple exposé par les auteurs, ce cadre permet de comparer les distributions de probabilités des différentes stratégies de prévention et de choisir la plus appropriée en fonction de la perception du risque qu’a le responsable. Un tel cadre peut être considéré comme une nouvelle méthode normalisée de comparaison et de sélection des stratégies de prophylaxie zoosanitaire intégrant des données et des principes à la fois techniques et économiques.


Resumen: La creciente integración de los mercados internacionales se traduce por una mayor exigencia en la coordinación de las políticas de lucha contra las enfermedades contagiosas de los animales, y es probable que en el futuro se agudice la demanda de medidas más estrictas para el control y erradicación de tales enfermedades. Para dar satisfacción a esta exigencia sería deseable la creación de un entorno de simulación informática capaz de tratar hipótesis del tipo «¿qué pasaría si?». Ello permitiría explorar las consecuencias tanto epidemiológicas como económicas de un cierto número de infecciones y estrategias de control.

Los autores proponen un marco de análisis económico flexible, que ilustran a continuación con un ejemplo. El sistema integra cuatro factores: cambios en el porcentaje de rebaños afectados, cambios en el volumen de producto, variación del precio del producto e integración económica. Cada uno de estos factores es definido de modo específico y posee sus propios datos de entrada y salida, en función de la estrategia de control que se considere.

En un ejemplo que ilustra el funcionamiento del sistema, se comparan las distribuciones de probabilidad de distintas estrategias de control, y se elige la estrategia óptima de acuerdo con el criterio que adopte el planificador concerniente al riesgo. Este marco de análisis puede ser considerado un nuevo enfoque estándar para la comparación y selección de estrategias de control sanitario, mediante la integración de datos y principios tanto técnicos como económicos.

Appendix I

Parameters used to describe the infection in the example

<table>
<thead>
<tr>
<th>State</th>
<th>Within-herd susceptibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not infectious and not immune</td>
<td>0.95</td>
</tr>
<tr>
<td>Immune</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Transition matrix

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not infectious and not immune</td>
<td>0.80 \times (1 - p_{i,p})</td>
</tr>
<tr>
<td>Immune</td>
<td>0.10 \times (1 - p_{i,p})</td>
</tr>
<tr>
<td>Infectious</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Starting distribution

<table>
<thead>
<tr>
<th>State</th>
<th>Percentage of herds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not infectious and not immune</td>
<td>7%</td>
</tr>
<tr>
<td>Immune</td>
<td>68%</td>
</tr>
<tr>
<td>Infectious</td>
<td>25%</td>
</tr>
</tbody>
</table>

Transmission rate (TR) = 10 herds week$^{-1}$
Overview of the literature concerning different characteristics which are important in the support of decision-making in animal health control

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>VI</th>
<th>VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herd (H) or national level (N)</td>
<td>N</td>
<td>H</td>
<td>H</td>
<td>N</td>
<td>–</td>
<td>H</td>
<td>N</td>
</tr>
<tr>
<td>Normative (N) or positive (P) approach</td>
<td>N</td>
<td>N &amp; P</td>
<td>N &amp; P</td>
<td>N</td>
<td>P</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Simulation (S) or optimisation (O)</td>
<td>S</td>
<td>O</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Dynamic (D) or static (S)</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Deterministic (D) or stochastic (S)</td>
<td>D</td>
<td>S</td>
<td>S</td>
<td>D</td>
<td>D</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Production change (P) and effect of export bans (E)</td>
<td>P &amp; E</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>–</td>
<td></td>
</tr>
<tr>
<td>Fixed price changes, using elasticities (E) or price-equilibrium models (PE)</td>
<td>E</td>
<td>PE</td>
<td>PE</td>
<td>PE</td>
<td>PE</td>
<td>PE</td>
<td>–</td>
</tr>
<tr>
<td>Cost-benefit analysis (C) or sensitivity analysis (S)</td>
<td>C &amp; S</td>
<td>–</td>
<td>C &amp; S</td>
<td>C &amp; S</td>
<td>C &amp; S</td>
<td>C</td>
<td>–</td>
</tr>
</tbody>
</table>

The corresponding references are as follows: I (9), II (11), III (17), IV (23), V (53), VI (37) and VII (41)

* * *

REFERENCES


