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Economics of animal vaccination

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Summary
This paper describes the steps that might be used in assessing the economic justification for using vaccination to control animal disease, and the way that vaccination is financed and administered. It describes decisions that have been taken with respect to preserving international trade, and issues related to protection of livelihoods. Regardless of the motivation for vaccination, its costs can usually be shared between the public and private sectors. Cost-effective vaccination requires methods of delivery to be adapted to livestock production systems. The paper concludes by suggesting questions around the use of vaccination that would merit further economic analysis.

Keywords
Animal disease – Economics – Livelihood – Vaccination

Introduction

The paper addresses two subject areas, namely: the economic justification for using, or not using, vaccination in disease control; and the way that it is financed and administered. Interested parties may include the following:

– governments deciding whether to permit or forbid the use of vaccination, or make it compulsory

– farmers deciding whether or not to pay for vaccine for their herds and flocks, and whether to comply with requirements to present their animals for vaccination

– those who produce and supply vaccine

– those concerned with the welfare of farmers and their animals.

Most readers will be familiar with the basic principles both of vaccination and of the economic analysis of animal health. The former are covered in this issue of the World Organisation for Animal Health (OIE) *Scientific and Technical Review*. Aspects of economic analysis and modelling of animal health have been dealt with in varying degrees of complexity by many authors (18, 30, 33, 37, 42, 45, 48). General thinking on animal health and livestock economics, including new institutional economics, has also been variously described by many authors (1, 12, 16, 26, 28, 40, 48, 49). A summary of economic methods for animal health was made recently by Rich *et al.* (32).

Rather than repeating what has been well described, this paper concentrates on the practicality of applying economic analysis to assessment of vaccination, by identifying a series of key questions and reviewing the way in which decisions have actually been made in different situations. A stepwise process is used to lay out the most important issues, although in reality, decisions are seldom as linear or clear cut as they are in conceptual models. The process is as follows:

a) The first step is to assess whether vaccination is technically viable; that is, whether a vaccine exists and can be applied safely and effectively.

b) Assuming that vaccination is technically possible, two economic questions may underpin the decision to apply it, allow it or forbid it, they are:

– whether the use of vaccination will adversely affect international trade in livestock products

– whether the use of vaccination could protect livelihoods, particularly those of vulnerable people, or otherwise reduce distress.

It is not impossible that conflicting answers will arise, and in this case, it is necessary to weigh objectives and make a choice, or to look for an acceptable compromise.

c) The next factors to be considered are the institutional and operational conditions that affect the assumptions underlying economic analysis. Here, two closely related points must be examined:

– the funding source for vaccination, which may be public or private or a mixture of both

– regardless of the source of funding, the delivery of vaccination should be cost effective. This means that the delivery process needs to be adapted to the production systems in which vaccination is applied, and the potential recurrent costs of vaccination should be examined carefully before a programme is started.

The remainder of the paper examines each of the above points in turn, and then concludes by identifying areas where animal health planners would benefit from further support or new economic analyses to assist in decisions about the use of vaccination in animal disease control.

Technical viability of vaccination

Vaccination may be considered for the following purposes:

– to stamp out an outbreak in a country, zone (a geographically continuous area separated from infected areas by a surrounding buffer zone) or compartment (a component of a management system under a common biosecurity regime, e.g. the biosecure production, slaughter and processing units of an industrial value chain, with animals and feed moved between units in biosecure transportation) that has previously been free of disease or free of virus

– to eradicate disease (when it is used in the early stages of a programme to reduce virus load)

– to establish and then protect a disease-free zone

– to achieve a low level of incidence of clinical disease in areas where it is endemic.

In the first case, that of stamping out a new outbreak, vaccination together with reduced culling may be considered as an alternative to widespread culling. Vaccinating in a ring around an outbreak and culling in a smaller inner ring reduces the number of animals that need to be slaughtered in the immediate outbreak control action. For this strategy to work, necessary conditions would include the existence of a safe and effective vaccine, and rapid onset of protection at individual level. Vaccination has been used in stamping out of foot and mouth disease (FMD) outbreaks, for example in the Netherlands, when insufficient personnel and equipment were available for culling. At the time of writing, ring vaccination was being reviewed by several countries for the control of highly pathogenic avian influenza (HPAI) since vaccines have been developed that provide good protection to poultry. The main technical concerns were that vaccinated birds must not increase the risk to humans, since they greatly reduce clinical disease but do not completely eliminate virus shed, and that birds could be adequately protected against spread in the poultry population when full protection was only conferred after two applications of vaccine. There is always a concern when using vaccination in an emergency situation that a sufficient amount of vaccine can be provided at short notice, since vaccine has a finite shelf life and manufacturers cannot afford to maintain large stocks against uncertain future orders.

Vaccination has been an important component in eradication programmes, including those involving progressive zoning, such as those for rinderpest in Africa and FMD in Latin America. The technical challenge in using vaccination for eradication is to obtain on a consistent basis sufficiently high levels of herd immunity to prevent virus spread (the protection level needed depends on the reproductive rate of the virus. It can be as high as 80% or considerably lower, depending on the ease of transmission and the opportunities for animals to come into contact), often under difficult field conditions. Rinderpest devastated African cattle herds in the 19th Century and had become very widespread in less virulent forms in the 20th Century. An effective vaccine was produced several years ago that confers lifelong immunity, and later, a thermostable form was developed that could be delivered without a cold chain. It was therefore possible, with annual vaccination programmes, to maintain a level of immunity in the herd sufficient to drive back disease. In many countries disease has reduced to a point where vaccination could be stopped and the few remaining outbreaks controlled with surveillance and stamping out. Vaccination against FMD, although it has been used successfully in control programmes, is less straightforward because the vaccines available against FMD offer only a short span of protection, and bi- or tri-valent vaccines are needed to protect against the many and changing virus strains.

When vaccination is used as a preventive measure to keep incidence below certain levels, a vaccine is needed that can be applied effectively (by farmers as well as veterinarians). It is applied in this way to deal with classical swine fever

(CSF) in parts of Asia and brucellosis in many countries. It is also used against Newcastle disease (ND) and rabies, where there may be reservoirs of infection in wild animals. ND occurs all over the world and sweeps through smallholder poultry flocks from time to time, causing high mortality. Well-tested vaccines exist that can be used as a preventive measure in less than optimal field conditions, and applied even without injection, and they offer the means for individual farmers to protect their flocks.

For some important diseases, such as African swine fever (ASF) and bovine spongiform encephalopathy (BSE) vaccines do not exist and the only possibilities for their control are good hygiene management to improve biosecurity of herds or stamping out measures (culling and disinfection together with movement control) to remove outbreaks. Even where good vaccines do exist, vaccination programmes must always be supported by surveillance and backed up by other measures.

When the basic technical requirements for using vaccination have been met, it can be examined for economic viability. Two important considerations facing decision makers are the use of vaccination in countries engaged in international trade, and the possible benefits of vaccination in protecting livelihoods, particularly those of vulnerable people. Each of these will now be examined in turn.

Vaccination and international trade

Figure 1 reminds us of the well recognised trend towards increasing international trade in livestock commodities, particularly from developing countries. In 1990 developing countries accounted for 30% of international trade while by the end of 2006 the figure was expected to reach 47% (23, based on Food and Agriculture Organization [FAO] data). Developing and emerging economies, whose resource base allows them to be competitive, have increasing importance in production, in particular the 'big three', Brazil, China and India (39). In many countries with strong livestock production growth, there continue to be problems with animal disease control. There has been a shift towards processed products among the industrial producers, in large part because of increased concerns about animal health and food safety regulations.

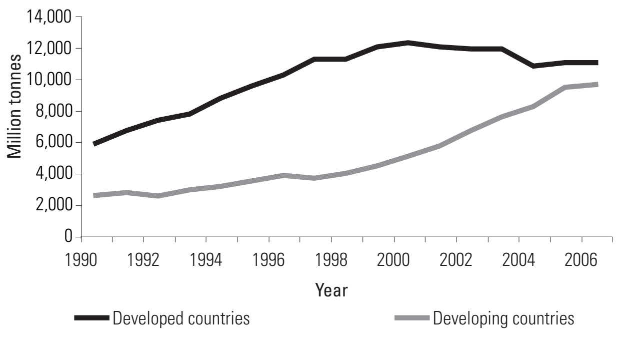

Fig. 1
Growth in world meat exports
Source: Morgan, 2006 (23)

The ability to export livestock and their products depends on equivalence of animal health and food safety conditions, particularly with regard to animal diseases that have been defined as notifiable by the OIE (50). Currently, countries where notifiable diseases are present have limited potential to export unprocessed livestock products or live animals to those that can prove they do not have the same diseases, although it is possible to export processed products such as heat-treated or de-boned meat. For exporting countries wishing to access premium markets, freedom from notifiable diseases forms a major preoccupation for their Veterinary Services and the commercial livestock sector.

Increasingly it is being recognised and defined in international guidelines that disease freedom may apply not only to a country but also to a zone or a compartment. While the concept of a zone is quite well accepted, that of the compartment is less so. Thailand has been exploring the possibility of defining disease-free and vaccination-free compartments for export of poultry (22) which might allow targeted vaccination in smallholder flocks outside the compartments. It has been difficult to arrive at a technically and financially viable design that is acceptable to importers. The concept of safe commodity trading also allows for some flexibility. Essentially, it argues that a certified processed product such as de-boned beef from a hazard analysis critical control point (HACCP)-accredited slaughterhouse should be exportable even if vaccination is being applied in other parts of the livestock sector. This has always been possible to some extent, since processed products are exported from countries that vaccinate against certain diseases. It is of great interest in the Horn of Africa, where ruminant meat from extensive systems is the main exportable product. Gradient systems (those that allow different conditions for different parts of the livestock sector) have many attractions. There are, however, concerns that flexible standards in animal health and food safety might actually mean double standards, with premium markets getting better care and attention while others are offered a second-class product. One way to prevent that happening is to pay attention to providing suitable services to all types of production system.

Importing countries free of disease and not vaccinating may decline to take animal products from countries, or zones, that vaccinate, and will try to control rare outbreaks by culling, disinfection and movement control rather than vaccination. A country trying to achieve official recognition of disease freedom can only do so after a progressive control programme and months or years free of any outbreak (the OIE regulations define precise periods for some diseases, for others it is a matter of negotiation between trading partners). Disease freedom when vaccination is applied, even if it can reliably be demonstrated that there is no clinical disease, is never considered equivalent to freedom without vaccination by importing countries that are free without vaccination (e.g. FMD vaccination can be used for a short time to control an outbreak in a previously free area, but it must quickly be withdrawn and the area monitored for some time before trade can recommence), even if the OIE *Terrestrial Animal Health Code* may not differentiate the requirement. The benefits of achieving and maintaining a premium export market can be considerable. Uruguay spent between US$7 million and US$9 million a year on FMD vaccination prior to 1997. Once it was declared free of FMD, it gained access to a beef market in the United States of America (USA) worth around US$20 million a year above the value of previous domestic sales (17).

When a country trades in livestock products on the basis of freedom from certain diseases without vaccination, the critical economic question will be: in the event of a disease outbreak, should vaccination be used to control it? When Botswana experienced a contagious bovine pleuropneumonia (CBPP) outbreak in the 1990s, the decision was made to use slaughter and compensation rather than vaccination for control, in order to re-establish its export market to the European Union (EU) more quickly, although a programme based on vaccination cost only 78% of one based on culling and compensation (19). Thailand was one of the first countries to report HPAI when a series of outbreaks began in Asia in 2003. By March 2004, the cost of compensation alone had been US$46.5 million, paid to 407,338 farmers. With disease in 51 provinces and a silently infected duck population in the wetland areas, it would have been a reasonable decision to move to widespread vaccination. However, Thailand's poultry meat export industry was valued at US$597,634,000 in 2003 (it held fifth place in the global export market, falling to 17th in 2004 [6]), so the decision was made to try to eradicate disease without vaccination. A house-to-house 'x-ray' survey was implemented to seek out disease, and all subsequent cases were rapidly investigated, reported and stamped out. These efforts greatly reduced disease but have not yet eliminated it, and recovery of the export trade was achieved largely by expanding processed products.

Countries in trading blocs try to create harmonious rules about animal health, so that countries within the bloc can trade with each other under reduced transactions costs. The countries of the EU try to remain free of notifiable animal diseases without vaccination, and when a member of the bloc experiences an outbreak there is peer pressure to control it by stamping out measures. In the United Kingdom (UK), an outbreak of FMD in 2001 was controlled without the use of vaccination, although at considerable cost in terms of lost animals. There were no major markets threatened at that time, as beef markets were closed due to BSE, the predominant lamb markets were for low value product to Spain and Italy and pork markets were for cuts that did not sell in the UK, but there was a strong political will to eradicate the disease. This was eventually achieved, but not without the loss of considerable numbers of animals, losses in other rural industries, psychological effects on farmers and concerns among the general public about slaughter of healthy animals (36). Risk modelling carried out after the outbreak suggests that vaccination with reduced culling might reduce the numbers of animals culled on disease grounds by 15% to 50%, although culling on welfare grounds might increase slightly (welfare culling may be permitted when animals are kept beyond their normal selling age and farmers cannot afford to feed them) (34). In 2001, the European Commission (EC) and OIE guidelines on the use of vaccination were very inflexible. Since 2001, the EC has revised its directives on FMD control to provide greater flexibility in the use of vaccination. At the same time, the OIE has agreed a reduction in the use of the 'holding period' before freedom from disease can be declared. The development of differentiating infected from vaccinated animals (DIVA) strategies – making it possible to distinguish in serological tests between antibodies from disease and those from vaccination – offers further potential for limited use of vaccination by exporting countries. However, there has not yet been a re-examination of the UK data to assess whether vaccination would be economically and technically viable under current regulatory conditions.

For countries engaged in international trade of live animals or unprocessed products, therefore, there will be hesitation in permitting vaccination to be used in disease control. In the event of an outbreak, a stamping out process that relies on culling and movement control rather than vaccination will promote a faster return to trade, provided that it is successful.

Protecting livelihoods and human well-being

Animal vaccination may have a role to play in protecting the livelihoods of producers and traders of livestock, and individuals employed in the livestock sector, particularly small-scale operators whose livelihoods are vulnerable because they have limited safety nets. Vaccination is likely to be beneficial to livelihoods in the following situations:

– when it can be used to control disease effectively with minimal depopulation, particularly in situations where adequate compensation for culled animals is not available

– when it prevents the disruption of national markets or allows markets to be restored quickly, thereby protecting the livelihoods of those who sell into the markets, and the providers of services, and those employed in the livestock sector

– as an 'insurance' against disease losses by private farmers or an investment in protection of an industry

– when it minimises the disruption of other sectors linked to livestock, such as leisure and tourism.

When stamping out measures are used to deal with an emerging or re-emerging disease, the effect on the national economy of the culling of even quite large numbers of animals may be minimal. Unfortunately, the effect on the livelihoods of those immediately affected may be severe. Depopulation of animals other than occasionally and on a very small scale can be badly damaging to livelihoods of smallholders and small-scale traders who rely on regular or instantly accessible cash flow from their livestock. Where the animals are owned or managed by women, as is often the case with smaller species, income from them tends to be used directly for buying food, and loss of this income has an adverse effect on household food security (7). In small herds and flocks, a certain level of risk is accepted and occasional disease outbreaks are taken as part of normal operation. However, in a widespread outbreak or culling operation where depopulation spans several villages, the safety-net herds and flocks kept with relatives may also be destroyed, leaving no easy means to restock. Even where effective compensation schemes are in place, they seldom cover the cost of lost production time and lost cash flow. In many countries, compensation is limited or faces considerable administrative challenges, which results in payments being inadequate or very delayed.

Distress suffered by farmers over destruction of apparently healthy animals is an additional although unquantified impact of widespread culling. Many farm families in Britain suffered from psychological shock after the 2001 FMD outbreak in Britain as did many of the culling teams. More recently, scenes of distraught children hiding birds from culling teams, and farmers refusing to let cullers enter their villages, have been a regular feature of HPAI control.

If vaccination reduces culling or the incidence of clinical disease, the positive impact on animal welfare can be seen as a benefit in itself, aside from the psychological impact on people who care for livestock. In the CSF outbreak in the Netherlands in 1997 and 1998 and the FMD outbreak in the UK in 2001, the large number of animals slaughtered as well as the high costs of control raised the question that much earlier use of vaccination in epidemic control may be appropriate (4). Animal welfare has an increasing importance in the livestock standards of Member Countries of the Organisation for Economic Co-operation and Development (OECD) and in premium markets for animal products.

At what point, then, should a government decide to bring vaccination into the control process for epidemic disease? An unchecked outbreak of a rapidly spreading disease may kill large numbers of animals. Halting it by means of a rapid and effective culling scheme will cause short-term distress but very little impact on livelihoods in the long term, particularly if it is possible to provide some form of compensation. When it becomes evident that culling will need to be widespread, or that outbreaks are spreading beyond control, a rapid decision to implement ring vaccination may save the livelihoods of many smallholders. In the areas of China with median poultry density, using ring vaccination in a 5 km zone with limited culling to stamp out an HPAI outbreak, instead of culling in a 3 km zone, has the potential to save the destruction of over 50,000 poultry in just one outbreak (38). Vietnam and Hong Kong are using targeted vaccination for control of HPAI, which has reduced both the number of new cases and the scale of culling.

Market shocks from disease outbreaks affect small and large producers, but in different ways, and have varying impacts according to the disease. Market shocks can be caused by consumer worries leading to loss of demand, by very severe depopulation, or by closing of markets on animal health grounds. Zoonotic diseases (i.e. those that can affect both animals and people and can be passed between them) that cause human death have the greatest effect on demand, as consumers lose confidence and switch from eating a product thought to be dangerous to others considered to be safer. Concern over BSE still closes markets from certain exporters (8). HPAI has caused short-term consumption and price drops for poultry in many affected countries, and in some countries not yet infected. In some cases the prices of substitute proteins have risen. Other diseases such as brucellosis, tuberculosis and cysticercosis are an accepted daily risk in many countries and do not create market shocks.

Large exporters have safety nets to deal with immediate production losses, but are very concerned about the maintenance of their markets and for reasons already discussed may prefer not to have vaccination applied. Small-scale operators have limited capacity to deal with loss of animals and the immediate outbreak costs. Large or small producers selling into domestic markets may be worried about quarantine measures, which can require animals to be kept beyond their normal sale time. Prices may fall if animals grow beyond a normal weight range, particularly if many are released onto the market at the same time when quarantine is lifted, and meanwhile the costs of keeping and feeding the animals are higher than normal.

Can the use of vaccination prevent any of these market disruptions?

Using vaccination to control zoonotic disease outbreaks is unlikely to mitigate market shocks caused by consumer fear, unless certification can be provided and consumers are convinced that products from vaccinated animals are safe to eat. For a purely animal disease, where an outbreak occurs in an exporting country or zone, there may be benefits to both export and local markets from using control methods based on culling rather than vaccination, provided that the outbreak is halted quickly. In Botswana, the export market for beef to the EU from a disease-free zone is an important generator of revenue, and the domestic market is supplied mostly by local producers outside the free zone, where vaccination can be used. The previously mentioned CBPP outbreak resulted in a ban on exports of beef to the EU, which proved damaging to domestic producers as well as exporters, because animals bred for export had to be sold on the domestic market, severely depressing prices (46). Analysis of the Zimbabwe beef sector in 2003 suggested that a similar effect would occur there if an outbreak of FMD closed export markets (27). The decision was made in Botswana to use culling rather than vaccination because it was believed that this would result in the fastest recovery of the export market, and this would be beneficial to all producers. Unfortunately, the outbreak took longer than anticipated to control, and resulted in the destruction of many animals outside the export zone (24).

Where the domestic market is the primary market and the export market is small or non-existent, and particularly when disease is endemic, there should be a considerable interest in using vaccination. Domestic markets do not exclude vaccinated animals provided that they are safe for humans to consume and the vaccine has been properly applied. Vietnam has recently examined its options for the control of CSF. Of all the measures that can be employed, quarantine (which does not permit pigs to be moved outside of their communes and therefore limits access to markets) is the most inequitable, because most of the cost is borne by producers while traders have a good chance of maintaining their market margins even though their cash flow may be disrupted (20). If several small outbreaks occur simultaneously (not uncommon), it is more equitable and less costly to apply ring vaccination rather than quarantine. For short-cycle species, if the use of vaccination makes it possible to keep domestic markets open, then it may prove to be very 'livelihoods-friendly'.

When using vaccination against a zoonotic disease, human safety and health must be taken into account and this makes the analysis more complicated. Economic analysis for human health generally uses a cost utility approach, where the expected rise in the number of quality adjusted life years (QUALYs) or disability adjusted life years (DALYs) in the population at risk is compared to the cost of achieving this result. By contrast, economic analysis of livestock production systems is more likely to estimate the monetary value of both benefits and costs. Few assessments of zoonotic disease control have been carried out that give equal attention to the human and animal side, but two examples are Roth *et al.* (35) on the control of brucellosis in Mongolia and Coleman *et al.* (5) on the poverty impacts of zoonotic diseases. Current planning for avian and human influenza control has looked at the costs of each side of the programme but it has been extremely difficult to make meaningful estimates of total benefits (3), since the risk of a human pandemic, while real, is almost impossible to quantify. Vaccination of wildlife against rabies as practised in Western Europe has the effect of reducing the costs involved in paying compensation to cattle owners as well as the threat to companion animals and people. In France, vaccination of red foxes was found to be more effective and cheaper than their depopulation as a way of controlling rabies (2).

Vaccination can also be seen as private or public 'insurance' to protect livestock. One example from a public perspective would be the widespread use of FMD vaccination in the EU until 1991, when policy shifted to maintaining disease freedom without vaccination. Vaccination is often used by producers as an insurance against loss of animals or loss of productivity, with the relatively small investment in vaccination far outweighing the potential reduction in productivity from disease. Large commercial producers, particularly those in value chains supplying supermarkets, work to tight delivery schedules and cannot afford delays caused by disease. Even for small producers under less stringent production requirements, investment in vaccination can be financially attractive. For example, in Vietnam it can be economically viable for smallholder pig farmers to pay for CSF vaccination, particularly for their breeding sows. The cost of annual vaccination breaks even when incidence is around 2% (20).

The livestock sector is never independent of other sectors, and in some countries models exist that make it possible to estimate the full impact of livestock disease. In Botswana, for example, the cattle sector has positive impacts outside of agriculture which can be affected by livestock disease (46). In both Thailand (29) and Malaysia, HPAI outbreaks caused a depression in tourism. The 2001 FMD outbreak in Britain had severe negative effects on rural economies because the ban on walking across farmland discouraged local tourism and FMD and its control generally discouraged international tourism. Approximately

£3.1 million of the total cost is estimated to have been borne by the public sector and the agri-food sector, with losses of £4.5 billion to £5.3 billion to other sectors, mainly tourism and leisure (4). Vaccination will be most helpful in situations where it reduces the spread of virus, so that the most stringent control measures can be limited to a small area, or reduces the outbreak time, allowing movement controls to be lifted sooner. Where an important tourist industry is affected by a zoonotic disease, human health concerns will take precedence.

Financing vaccination

Vaccination is financed from a variety of sources, including national governments, international bodies and private organisations; cost sharing is quite common. The policy for funding is usually derived from a mixture of economic concepts and practicality. Conceptually it may be determined on the basis of public and private goods, where a private good is one that is funded entirely or mostly by private individuals (in this case farmers). The conventional rationale behind this decision is that the 'good' in question has high excludability (it is easy to prevent people from using a service if they have not paid for it) and high rivalry (use of it by one person limits use by others) (11). If it has low excludability and low rivalry, it is a public good. Alternatively, the externalities generated by an action may be considered (16). Externalities occur where the actions of one person have effects on others who are not involved in the original transaction, but the person causing the problem is not required to pay compensation for damages. Where high externalities occur and can be traced to a source, it may be possible to apply a 'polluter pays' principle, but in the case of infectious animal diseases this is difficult.

It is easy to understand why vaccination against, say, mastitis, or theileriosis might be considered a private good. The presence of mastitis in one herd or flock creates no significant externalities. It is possible to make vaccine available only to those who pay for it, and in circumstances where supply is limited, use by one person might limit use by others.

Control of a transboundary disease such as CBPP or CSF, seems to be a different case since there are clear externalities, and it is hard to apply a 'polluter pays' principle. Controlling it in one herd reduces the risk to neighbouring herds that may not have contributed to the control effort. Nevertheless, Twinamasiko (47) made a convincing argument that control of CBPP could be treated as either a private or a public good in different parts of Uganda depending on the prevailing epidemiological situation. Externalities in areas where the disease is widespread, and where the preference among herders is to treat clinical disease with antibiotic, would be different from those in areas where it seldom occurs.

In Vietnam, where CSF is endemic, its control by vaccination is treated almost as a private good although it has externalities. Government campaigns are run but not with sufficient regularity to provide high levels of herd immunity, and vaccine is available for purchase from the government by private veterinarians for their clients. In some places it can be bought by farmers or animal health workers from local licensed feed and drug shops (15, 20).

Many preventive vaccination programmes have a cost sharing element, even when vaccination is delivered by government campaigns. This reduces the strain on limited government animal health budgets, although government-run cost recovery schemes only transfer costs from one part of the economy to another without generating any production, while adding administrative charges (13). Payment at point of delivery is a popular way to get cost sharing in government vaccination programmes but not without problems. In the late 1990s there was a cost recovery scheme for CBPP in Uganda. People distrusted the vaccine and were unwilling to use it, and an increasing scale of charges over a short time compounded the problem. Some private practitioners were unwilling to recommend the use of CBPP vaccine because it adversely affected customer relations (31). Ring fenced taxation, reciprocal (joint funding) schemes and payment at point of delivery, have all been used in the livestock sector. Reciprocal arrangements are used in animal health funds in Australia, to promote risk sharing.

Generally, it seems that animal owners are prepared to pay for vaccination when they perceive a benefit from it. Leonard (16) cites an example where externalities, rather than the private/public nature of the good, would lead Ugandan herders to choose vaccination against prevalent epidemic disease (with high private and public benefits) but not to opt for quarantine (with negative private, but high public benefits). In the Gambia farmers are willing to pay for vaccination against peste des petits ruminants and ND when there is an outbreak but less so as a routine preventive measure (personal communication from members of the Veterinary Services). In other situations where the risk is perceived differently by different stakeholders, large commercial producers have opted to cover the costs or even deliver vaccination to smallholders close to them, and thereby reduce the risk to their own herds.

It may help to rationalise cost sharing if the direct cost of vaccination is split into its different elements and each considered separately. Vaccination direct costs can be split into sunk or investment costs (including vaccine development and vaccine delivery infrastructure) and variable or recurrent costs (including vaccine delivery and vaccine). The investment costs can be made by either the public or private sector, or a combination of the two. Public investments are justified for diseases where there are strong externalities and important social and poverty reduction issues. Public investments could also reduce the costs of vaccine and its delivery. Payment for variable costs of vaccination depends on the objectives of the disease control (control or eradication), the disease itself (particularly the externalities it generates) and the systems in which the disease is found (extensive/intensive; communal or private land ownership). McInerney's (18) theoretical work paid much attention to the variable cost issues at farm-level, but ignored the investment costs. His framework has been applied in various studies, for example in farm-level disease control measures (40), and has been extended to include fixed costs such as vaccine development and vaccine delivery infrastructure (9, 44). However, making the best use of investment costs in vaccination requires that campaigns be short and sharp in order to eradicate diseases as quickly as possible (36). Unfortunately, many vaccination campaigns are long processes, where herd immunity is developed slowly, and as the impact of disease is reduced, there is less private incentive to vaccinate. Long campaigns favour returns on the original investment cost but are not a useful option to society. It may even be better to delay vaccination until vaccine delivery infrastructure is ready and farmer interest is at a maximum so that herd immunity is built up very quickly.

Cost-effectiveness and the delivery process

If vaccination is to be used as part of a disease control strategy, it needs to be delivered in ways that are cost-effective (i.e. that minimise the recurrent costs per animal protected), paying equal attention to the 'effectiveness' and 'cost' sides of the equation. Effectiveness is increased if livestock owners want vaccination and it is provided in a form and manner that is convenient to the people who manage the animals and at the same time preserves the quality of the vaccine. Recurrent costs include direct costs (those of getting the vaccine into the animal) as well as indirect costs (lost productivity as a result of vaccination). Direct costs will be reduced if there is a streamlined delivery chain for getting the vaccine to the people who use it, while indirect costs are reduced if the vaccine does not cause adverse reactions and the vaccination process minimises disruption and stress.

Because some of the direct costs are 'lumpy' (they cannot be broken down into very small units), such as transport and human resources, there may be some economies of scale attached to mass campaigns, but it is unwise to assume that this will always be true. The cost per protected animal will be determined by a number of factors. Some factors are specific to the vaccine itself: the cost of a dose, the length of time over which it is protective, the way in which it needs to be applied, the number of doses needed to confer protection and the possibility of side effects. Factors specific to the vaccine interact with factors for the species and production system. Even where there is potential for economies of scale, the animal health system may not have the capability to deliver it, and there is a need for investment in veterinary services in many parts of the world (9). The cost of delivering vaccination to an animal under the Pan African Rinderpest Campaign ranged from 0.27 to 1.71 ECU, with vaccine making up 5% to 33% of the cost (41).

For a cattle or sheep ranching system in Australia or Latin America, the largest element of vaccination cost is that of collecting animals together for vaccination. As well as the direct costs of assembling animals, there are indirect costs when stressed animals lose weight or even abort fetuses. There are considerable economies in using a vaccine that need only be applied once a year, at a time when animals are being mustered for other activities, and can be given easily to semi-wild animals passing through a crush.

For a pastoralist system in Africa, the timing of vaccination may be critical. Rinderpest is the only significant livestock disease to have been almost eradicated. Without the widespread use of strategic vaccination, it is doubtful that eradication could even have been contemplated. When a thermostable vaccine was developed, it became possible to combine traditional, widespread campaigns using cold chains with unconventional and participatory approaches in remote areas, but institutional factors still hampered the design of vaccine delivery. A benefit–cost analysis was used (25) to examine the reasons why pastoralists in northern Kenya did not present animals for vaccination, when an effective vaccine was available that created no adverse side effects. The answer was simple: at the time that the study was carried out, rinderpest in northern Kenya was occurring spasmodically, and sometimes in a form that did not cause high mortality in cattle. Because of the constraints of veterinary budgets, vaccination campaigns were held at times when animals were widely scattered. Bringing animals to a central vaccination point required a trek across country where cattle raiding was common. The chance of losing an animal to raiding when bringing it for vaccination was considerably higher than the risk from rinderpest in an unprotected animal.

Another consideration in pastoralist systems may be a process that allows the animal owners or herders to administer the vaccine, even if this is done under the supervision of a veterinarian and in a mass campaign, since the indirect costs of lost production will certainly be lower if animals are not stressed. To further reduce indirect costs, a system that allows animals that normally graze together to be vaccinated in cohorts will minimise the chances of being infected with other diseases.

Smallholder dairy systems require a different approach. Animals are housed in ways that make them easily accessible, in smallholdings that are often close together. Moving them to central vaccination points will result in indirect costs from lost milk production. For private good vaccines, such as the infection-and-treatment method of immunisation against theileriosis, immunisation at home by a private animal health practitioner or the owner is financially optimal. Even where vaccination against infectious diseases is provided through public campaigns, it may be preferable to have the animals vaccinated at home through contracts to animal health workers or private veterinarians and bear the additional direct costs of delivery.

Monogastric livestock, with short breeding cycles, offer considerable challenges in designing vaccine delivery. To achieve 80% protection against CSF in the smallholder pig population of Vietnam requires three campaigns a year by the Veterinary Services (20). As an alternative, making vaccine available at local level, through registered providers, gives pig owners the opportunity to vaccinate at the most appropriate time in the production cycle. An established feed and drug shop that invests in vaccine sales can break even in the second year of sales. Successful operation is dependent on farmer confidence and understanding of the benefits, assured supply of quality vaccine and regular inspection to ensure that the cold chain as far as the supplier is maintained. Two provinces that adopted this approach found that vaccine uptake increased, even though owners were asked to pay the full cost of vaccination when it was privately delivered and only part of the cost when it was provided by government campaigns.

To effectively immunise backyard chickens can require four to six campaigns a year, which is clearly impractical for Veterinary Services, even in densely populated Asian systems, where the cost of delivering a dose of vaccine can be less than US$0.06 (J. Hinrichs, personal communication), compared to US$0.38 in rural Africa (10). Recognising this, providers of ND vaccination have experimented with vaccines that can be given in feed and water by the poultry owners. Even for commercial systems with confined birds, handling individual birds to deliver vaccine by needle is time consuming and causes production losses, so other means are preferred. Where production cycles make it impractical for government Veterinary Services to administer vaccine, the role of vaccine delivery shifts to the private players in the animal health system, leaving the government with the responsibility for quality control and providing impartial information.

Smallholder cattle, as well as sheep, goats, pigs and chickens, are often owned or managed by women, yet few vaccine delivery processes are designed with women's requirements explicitly taken into account. These might include: small numbers of doses in a bottle to reduce cash payments; delivery to a place near the homestead; training women to recognise whether the provider has an effective quality management system; information on vaccine use in something other than written form, since in some countries illiteracy is highest in rural women; information about vaccination provided to children in schools, since children are often sources of information for their mothers and grandmothers. The Intermediate Technology Development Group in Kenya and FARM-Africa in Ethiopia deliberately trained female community animal health workers and paraveterinarians to work in production systems where women normally care for animals.

It has been suggested that research into animal health technology should be measured against a deliverability checklist of accessibility, acceptability, affordability and sustainability in order to make a link from the development of the technology to the expected economic outcome of its application (21). The same factors might provide a check against the assumptions for effective delivery of vaccine. On the supply side, financial sustainability of the delivery is related to the performance of the value chain for vaccination. Value chain approaches have been used extensively in manufacturing and horticulture, and to a lesser extent in the supply of livestock products, but very little in the analysis of livestock service delivery.

In addition to cost-effectiveness in protecting individual animals, which is critical for both short, sharp campaigns and longer-term programmes, the economics of vaccination are affected by the length of time over which it needs to be applied. Countries that use vaccination as part of an eradication programme, or to maintain an acceptable incidence level of an endemic disease, may be faced with considerable recurrent costs over a long period.

Vietnam, intending to commercialise its pig sector and expand the pork export market, began exploring the possibility of a disease-free zone in 2002. Between ten and fifty outbreaks of FMD were being reported a year to the OIE, while CSF was considered to be endemic, with an incidence rate below 5% annually. After analysing the production and movement patterns of ruminant livestock and pigs, two neighbouring provinces on the north-east coast were identified, that might be progressively declared free, first of FMD and then of CSF, over a ten-year period. Vaccination was expected to play an important part in removing CSF from the area. Figure 2 shows the estimated costs of the scheme year by year, with a gradual shift in recurrent costs from vaccination (which was withdrawn into the buffer zone) towards changes in the management

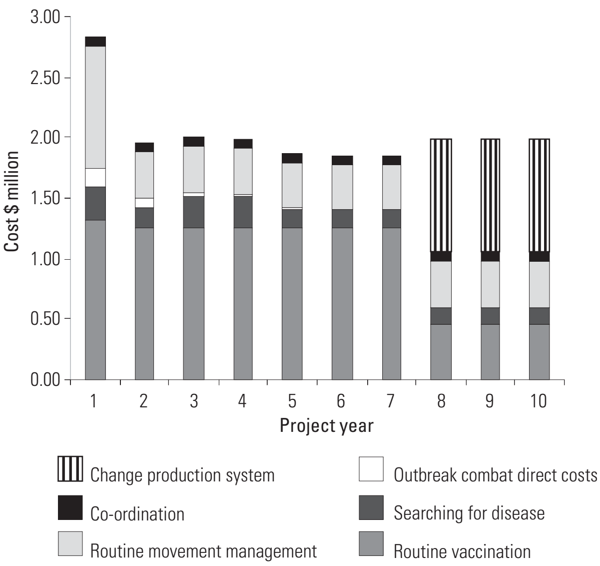

Fig. 2
Costs of establishing a classical swine fever and foot and mouth disease free zone in two provinces of Vietnam
Source: Taylor *et al.*, 2003 (43)

of pigs (chiefly, removal of swill feeding). This pattern would also represent a shift from public to individual private costs, since the costs of compulsory vaccination would be borne by the government (even if revenues were partly raised from an earmarked tax on the livestock sector), while management costs would be borne by individual farmers.

Hong Kong used an enormous and rapid culling operation to control an outbreak of HPAI in 1997, culling all commercially reared chickens. In 2001 all poultry in markets were culled. Since 2002, however, the strategy has changed to widespread vaccination and limited culling. Vaccination is now compulsory for all poultry, given that the risk of virus incursion will continue into the foreseeable future, but it is not being used in isolation, as strict biosecurity and surveillance measures have been introduced at markets and retail points. The number of poultry farms is gradually being reduced through ex gratia payments to farmers who surrender their farm licences (38).

The examples in this paper suggest that decisions around the use of vaccination are seldom clear-cut and benefit from a wide range of information about the economic and institutional conditions of the livestock sector. The final section examines constraints in applying economic assessment to the planning of animal vaccination and highlights areas that would benefit from further work.

Conclusions

Decision makers faced with emerging and recurring diseases need good decision support tools to decide when it makes economic sense to deploy vaccination; these should include not only epidemiological and economic models, although these are important, but information about consumer and producer behaviour that underpins the assumptions made by modellers. Ideally, they would have access to tools applicable for several species, adaptable for different types of major disease, to assess the probability of risk under a range of situations, as well as up to date production, price and trade data, and agreed priorities for different stakeholders against which to measure predictions. These conditions are rarely in place in advance of a crisis, and may not be met even when a longer planning horizon is available. Animal health planners, like planners in other sectors, are forced to make 'satisficing' decisions that make the best use of the available data in a limited time span. Most of the published work on the economics of animal health is based on problems that have already passed, although they carry lessons for the future.

The examples described in this paper, together with comparable analyses for other animal health problems, suggest certain imperatives for social scientists charged with supporting the development of animal health systems.

a) It is never too early to make contingency plans. Even for emerging diseases with no vaccines currently available, it is possible to develop risk assessments and computer models and carry out sensitivity analysis for different prices and protection levels. There is a growing need to balance the needs of different stakeholders as livestock markets become more globalised, and this means that questions about the use of vaccination need to be asked early in the planning process. Public opinion on animal welfare, and concerns about loss of livelihoods, have thrown up questions about the automatic use of widespread culling to control outbreaks. However, vaccination programmes may require prior investment in the animal health system.

b) We are not beginning from zero. There have been more than twenty-five years of work in combining epidemiological and economic models to analyse animal health programmes, including vaccination, in cattle, pig and poultry systems. While models always need to be adapted to make them situation-specific, a lot is now known about developing quantitative tools. However, there are only rare examples of the same tools being re-used or further developed. It is time to examine carefully the role that models play in the animal health planning process and whether they might be better used. Some initiatives have been taken in this direction (14, 42).

c) Animal health economics has placed a lot of emphasis on quantitative modelling. There is a need now to place equal emphasis on the assumptions underlying models, which result from social and political conditions and institutional arrangements. Animal health economists can also borrow from business analysts, using tools such as value chain analysis to revisit the design of animal health systems and the delivery of vaccination and other inputs. Work has been done in all of these areas analysing these conditions, but we have yet to develop planning teams that are truly multi-skilled or contain people with 'T-shaped' skills (i.e. a strong grounding in one disciplinary area, and sufficient training or experience in others to be comfortable with problems that cut across several disciplines).

d) Some specific areas would benefit from more attention. One would be a review of the economics of vaccination under the latest regulations, including the use of DIVA. There would also be value in developing more country and production system specific models to decide when to switch to vaccination, and applying them with a range of cultural and institutional assumptions, since outbreaks of notifiable diseases are prone to taking longer than anticipated to control, and having a more costly impact than expected. Given the rise in emerging zoonotics, and the increasing interest in food safety in most countries, these areas may require more attention in the future. Finally, there is room for a more detailed review of ways to make vaccination more cost-effective. These may include regional co-operation in vaccination task forces, and increasing use of animal health workers and private individuals in vaccine delivery, with a variety of organisational structures.

This is an interesting time for animal health economists. With a body of knowledge on which to build, technology to assist with analysis, and increasing understanding of the importance of many different aspects of social science in planning and policy making, there are excellent opportunities to fine tune the planning of animal health, including the use of vaccination, to make it user-friendly and cost-effective under many circumstances.

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Économie de la vaccination animale

A. McLeod & J. Rushton

Résumé

Les auteurs proposent une méthode permettant d'évaluer pas à pas le bien-fondé économique de la vaccination en tant qu'outil de lutte contre les maladies animales et de vérifier le financement et la gestion des campagnes de vaccination. Ils décrivent les mesures qui ont été prises pour préserver le commerce international et abordent d'autres questions liées à la protection des moyens d'existence. Quel que soit le motif à l'origine de la vaccination, les secteurs public et privé devraient en partager les coûts. Pour que la vaccination soit rentable, il convient de prévoir des modes d'administration adaptés aux systèmes de production animale. Les auteurs concluent en soulevant un certain nombre de questions économiques liées à la vaccination, qui mériteraient un examen plus approfondi.

Mots-clés

Économie – Maladie animale – Moyen d'existence – Vaccination.

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Aspectos económicos de la vacunación animal

A. McLeod & J. Rushton

Resumen

Tras explicar los pasos que cabría seguir para valorar la conveniencia, desde el punto de vista económico, de utilizar las vacunas para controlar una enfermedad animal, los autores describen el modo en que se financia y gestiona la vacunación. Después exponen las decisiones que se han adoptado con respecto a la protección del comercio internacional y a temas relacionados con la salvaguarda de los medios de subsistencia. Con independencia de los motivos que subyazcan a la vacunación, en general cabe repartir sus costos entre el sector público y el privado. Para una campaña rentable se necesitan métodos para administrar la vacuna adaptados a los sistemas de producción ganadera. Los autores concluyen proponiendo una serie de temas ligados al uso de la vacunación que merecerían un análisis económico más detenido.

Palabras clave

Aspectos económicos – Enfermedad animal – Medio de subsistencia – Vacunación.

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