Chapter 2

Economic determinants of farmer decision-making related to animal disease

This chapter reviews the major economic and financial issues of farmers' management decisions related to livestock disease. Farmer decisions are first examined from the perspective of cost-minimising or profit-maximising with no risk, uncertainty or information issues, which is most appropriately applied to endemic diseases. The role of risk and uncertainty in farm decisions is then examined, as are farm incentives in the presence of information asymmetries. This analysis provides insights that are relevant to epidemic diseases. Finally, the role of the farm industry structure and spatial effects in disease management are examined.

2.1. Farmer disease management decisions under certainty

- In a basic economic model, farmers prevent and control disease so that expected marginal benefits equal the marginal costs of those activities.
- Expenditures on disease prevention and control have diminishing returns, so it is often not economically optimal to prevent all expected losses from disease.
- Because of the negative externality associated with disease, farmers may under-invest in prevention and control relative to a social optimum.
- Technological improvement and (or) government action to lower prevention and control costs would shift a loss-expenditure frontier, resulting in a private cost-benefit solution with less disease.
- In making decisions on disease management, farmers must be able to understand the options they have related to disease biology and public action on the disease in question.
- One role of policy with regard to farmer profit optimisation is to equip farmers with knowledge and cost-efficient techniques to prevent and control diseases.
- Many biosecurity practices prevent from multiple diseases or vectors to develop; considering these benefits across diseases can lead to greater efforts and investment in biosecurity and surveillance.
- Dynamic relationships between producer choices and disease status may make complete disease eradication a sub-optimal strategy.

Farming as a business enterprise drives food production in OECD countries. The financial aspects of farming include profitability (generating returns), solvency (possessing adequate equity), and liquidity (ability to pay bills as they are due). Animal diseases may decrease profits through market and morbidity losses. Mortality losses of livestock directly affect farm wealth. Lost profitability and wealth can threaten farm financial viability.

Livestock producers continually face decisions with respect to diseases. These management decisions are either *ex ante* to the occurrence of disease, and include prevention measures in susceptible herds, or they are *ex post* and regard control measures when diseases occur (Chi et al., 2002). The probability of infection from a given disease depends on farm practices (prevention) as well as the prevalence rate in host populations (livestock, wildlife, and humans) in the relevant area.

The private benefits of livestock disease prevention and control include higher production as morbidity is reduced, lower mortality or less early culling, and avoided future control costs. With respect to prevention, farmers can allocate operating resources or investments to biosecurity programmes. These programmes often involve limiting livestock contact (e.g. via quarantines and controlling the movement of new livestock), as well as preventing other potential vectors of disease from entering the farm (e.g. wildlife or human contact). In addition, farm biosecurity may involve testing livestock and feed prior to purchase, strict sanitation regarding the possible ways that disease may be introduced on the farm, including via people and vehicles entering the farm, separating new-borns from infected dams, and protecting feed supplies from wildlife. Farmers control disease by monitoring and testing their own herd and reporting relevant infections to authorities. Treating disease is possible in some cases and may involve medicines as well as veterinary visits. In situations where recovery from the disease is impossible or treatment expenses are economically prohibitive, depopulation and culling of animals may be the only recourse. Early involuntary culling has long-term implications for livestock capital stock and significant costs related to animal replacement.

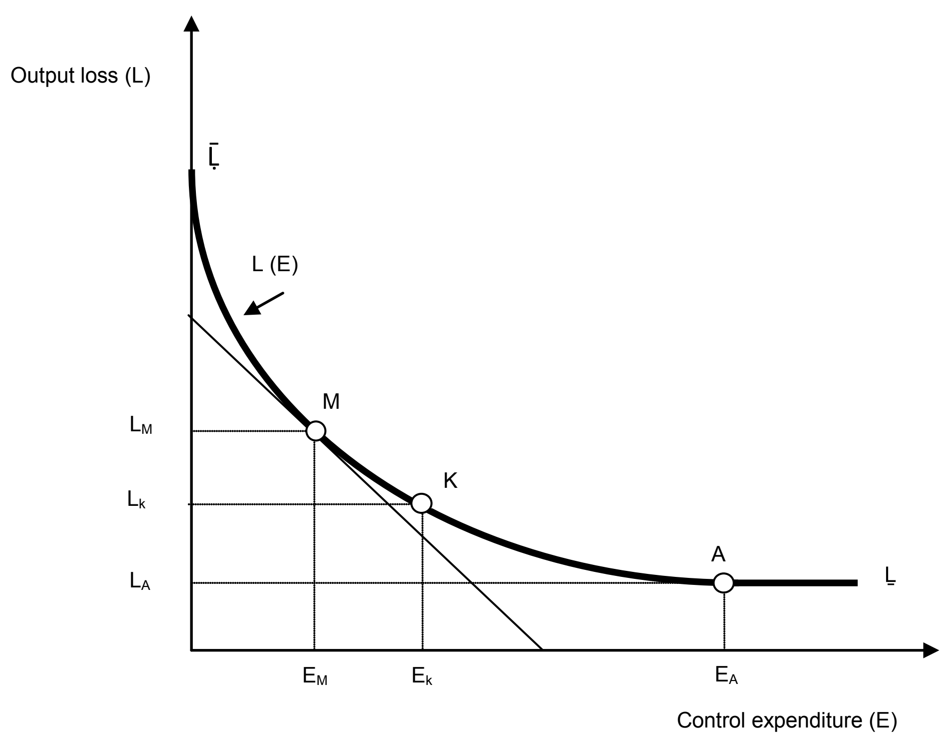
The motivations of farmers to control disease are to avoid livestock mortality and related replacement expenses, livestock morbidity and related production losses, increased veterinary expenses, and potential losses from business interruption when government programmes mandate the slaughter of entire herds or flocks. Farmers' motivations to shirk disease control include time, labour, management, and capital constraints.

The basic economic model of farmer decision-making related to disease management

McInerney et al. (1992) developed a decision model for disease management where the farmer trades off the costs to control disease and avoided losses (Figure 2.1). An output loss implies a benefit that is taken away (e.g. production loss) or an unrealised potential benefit. Losses are reductions on the output side of a process due to livestock morbidity or mortality. By contrast, some economic effects are expenditures (E). They represent resources that have to be allocated either to moderate the impact after a disease occurs or to avoid disease. The negative economic effects of a disease appear in one or other form, so that the total economic effects of a disease occurrence (C) are: $C = L + E$. L(E) is a loss-expenditure frontier that shows the relationship between control costs and avoided losses. If no action is taken to control disease, the losses would equal ($\bar{L}$) on the vertical axis. If expenditure is incurred for control of disease (points M, K and A), this will reduce disease losses (to L_M, L_K or L_A).

This framework employs two key assumptions. First, there is a trade-off between output losses and control expenditures – all other things being equal, higher disease control expenditures result in lower losses. Second, control expenditures have diminishing returns – as they increase it becomes more expensive to reduce losses.[1] One implication of diminishing returns is that economic cost of disease management (C) has optimal level, i.e. the point beyond which adding an additional unit of expenditure would reduce loss by less than a unit.[2] The implication is that it will not generally be economically rational to avoid all expected losses from disease (Dijkhuizen, et al., 1995). As drawn, the frontier, beyond point A runs parallel to the horizontal axis indicating in this example that some positive level of disease loss ($\underline{L}$) is unavoidable. This assumption is justified when diseases are unavoidably present in reservoirs or adjacent to the livestock operations. A new technology that lowers the control cost, public management programmes that reduce the density of disease, or government programmes offsetting the losses with indemnity payments would shift the frontier down and result in a situation with less disease.

Figure 2.1. Farm trade-off between disease loss and control expenditures



Source: Adapted from McInerney et al. (1992).

Chi et al. (2002) built on ideas of McInerney et al. (1992) and put them into a more formal economic framework of damage control inputs. The authors suggest that the optimal level of disease control, and the consequent disease level, cannot be determined using the same framework as for conventional inputs that tend to increase output levels with higher use. Instead, following Lichtenstein and Zilberman (1986), they consider disease control to be a damage control input because it acts to prevent output from falling, rather than to further enhance production. The farm decision is thus posited as maximising profits by choosing preventive and control measures as inputs in addition to standard production enhancing inputs. Chi et al. (2002) found the standard marginal benefit equals marginal cost for standard inputs, prevention inputs and control inputs.

Producers are concerned about the direct cost of the disease. They will minimise the costs of prevention and curative activities insofar as they pay those costs (i.e. costs are not off-set by government indemnity or disaster payments). These considerations are irrelevant if the producer choice is limited because government programmes mandate a response. This is true in the case of several livestock-borne diseases that pose a direct human health threat or cause large economic damages to the livestock sector or related industries.

The cost-benefit approach also leads to a distinction between the private and social costs of disease management and the existence of disease externalities. Beyond private impacts, animal disease has economic impacts across the wider economic system. This concerns food safety, human health, sanitary reputation to maintain access to export market, and broad spill-overs of disease on business sectors along the food chain. The private cost (C) for farmers does not reflect the full social cost of disease management, implying that private producers do not have inherent incentives to invest in disease management up to the "socially optimal" level which takes into account all externalities of animal disease. The frontier of the social economic cost of disease managements is thus always above the private frontier L(E). The existence of animal disease externalities is the principal economic justification for public investment in animal biosecurity. Furthermore, individual producers may have many objectives when they make investment decisions. Kristensen and Enevoldsen (2008), for example, found that the level of investment in herd health management on Danish dairy farms would never be at the socially optimal level because returns to investment were often better in other areas, and short-term gains were valued more than possible larger long-term gains, i.e. the time value of money and certain pay-off.

To make decisions regarding disease management producers must understand the options they have relative to the disease in question. These options depend on disease biology, prevention techniques, tests for infection and their costs, treatments available, market reactions, as well as industry and government programmes and policies. Disease biology includes transmission modes and rates, disease evolution (e.g. length of time to infectious period), production losses associated with the disease, and mortality rate (where applicable). Preventing the spread of disease often involves movement restrictions and quarantines. Treatment may include medicines and services to assist recovery. Market reaction involves the change in price for infected livestock and livestock products (which may result in a price of zero). Industry and government programmes may include indemnity payments, quarantines, test and cull programmes, or required depopulation and resulting business interruption losses.

Biosecurity economies of scope and preventive spill-overs

It is common practice in the veterinary literature to consider on-farm management on a disease-by-disease basis, in large part because observational or case-control studies are designed to identify management "risk factors" for infection. If each disease is considered as an independent event (i.e. by making biosecurity and health management decisions on a disease-by-disease basis), the full scope of disease management actions are ignored. A preventive spill-over exists whenever a health management or biosecurity practice yields preventive returns for more than one disease, such as control measures that reduce the probability of disease transmission to a facility. For example, improving sanitation practices of poultry production may help prevent both new castle disease and avian influenza.

From an economic standpoint, estimations of disease control functions should take into account the potential for disease management practices to affect the prevalence of multiple diseases, so that resources can be allocated efficiently. Preventive spill-overs may be thought of as either multi-product outputs of individual management practices or as input externalities, which may be either positive or negative. If management practices are viewed as livestock production inputs, then the notion of preventive spill-overs suggests that biosecurity practices are non-allocable factors in the sense that shares of the input cannot be allocated to the prevention of a specific disease or set of diseases and not to others.

Dynamic feedbacks in disease management

The economic analysis also emphasises the interactions between human decisions and epidemiologic state, that is, the feedback between disease management decisions and the evolution of the epidemic. Horan et al. (2010) describe multiple connections of epidemiology with human behaviour: culling rates are determined by a chosen combination of testing and removal efforts, the sub-populations under quarantine are also the result of human choice, domestic animal movements depend on economic activities, such as trade, while densities of wild populations as vectors of disease can also be influenced by wildlife programmes. All these choices appear in epidemiological models as parameters. A further idea is that human choices change as the disease situation evolves. Thus, as herd densities decrease through a density-reducing strategy, producers have fewer private incentives to invest in tests and slaughter of infected animals because of diminishing returns to these investments.

A consideration of dynamic feedbacks in the biosecurity system changes the perspective on optimal disease management strategies. Epidemiological strategies that abstract from these feedbacks generally assume that: (a) the objective is disease eradication, with management metrics based on the disease-free equilibrium, and (b) human behaviours are an external force on the disease dynamics. Alternatively, the bioeconomics approach joins human behaviours and disease biology in one system where human behaviours are endogenous to the analysis. The bioeconomic approach does not impose complete disease eradication as an explicit objective – it uses economic criteria in conjunction with epidemiological modeling to determine the economically optimal level of disease control (Horan et al., 2010). With this approach eradication is only optimal if its marginal benefit outweighs the cost. Fenichel et al. (2010) find that the bioeconomic approach may or may not optimally result in eradication but that in all cases it yields a larger net present value than does the conventional disease ecology approach.

2.2. Risk, uncertainty, and farm decisions

- Farmer decisions depend on their identification of risk; if farmers incorrectly identify risk, they may not act.
- A policy implication is to facilitate risk identification by farmers; better information on the presence, spread and consequences of disease can facilitate farmer decisions.
- Risk-averse farmers are likely to make greater efforts to reduce the probability of disease, leading to lower disease occurrence.
- Disease outbreak changes risk perception, with farmer responses during an outbreak likely being different from their responses during peacetime.
- Insurance can shift the composition of investments towards riskier production activities.

The discussion so far has left aside risk or uncertainty as part of producer livestock disease decisions. This section considers decision-making under risk and uncertainty which most appropriately applies to epidemic diseases. Animal diseases, and in particular epidemics which require a government response, are major sources of risk for farmers. Meuwissen et al. (2001) found that epidemic disease which is viewed as the second largest source of risk is essentially linked to price risk. In that study, non-epidemics ranked 17 out of 22 sources of risk. Baltussen et al. (2006) show that epidemic disease risks are perceived as highly important concerns amongst Dutch dairy, pig and poultry farmers, both in terms of their probability and possible effects. Non-epidemic diseases were typically perceived as less important.

Risks identification and farm risk management strategies

The types of risk faced by an enterprise are important in considering farmer perceptions and decisions. Mikes et al. (2015) define the types of risk as preventable, strategy execution, or external risks. Preventable risks are those that arise from routine operations. Preventable risks should be a focus of routine management and should not be tolerated; one might consider, for example, diseases that can be prevented by vaccination or common animal husbandry practices. Strategy execution risks are those that firms take in order to achieve higher returns; in farming, this might include the risk of infection from bringing in outside livestock during herd expansion. Firm managers can identify and influence the likelihood and impact of strategy execution risks, but some residual risk will remain. External risks arise from events the farm manager cannot influence. An example might be a local outbreak of foot-and-mouth disease due to border protection failure. Farm managers should consider responses and resiliency to external risks. Delineating risks in this way is useful with respect to farm animal disease management decisions because these decisions are primarily concerned with preventable risks. However, this framework suggests that farm managers should consider the potential for disease derived from strategy execution activities. If farmers incorrectly assume a particular disease is external, they will ignore it. Thus, one important job governments can facilitate is risk identification.

As a risk management exercise, animal disease management requires assessing the likelihood of disease. For locally endemic diseases, this is part of standard herd health management. For exotic infectious disease, this assessment will be quite difficult. According to Hardaker et al. (1997), there are many potential psychological pitfalls in making probability judgements. Other pitfalls include avoiding uncertainty instead of managing the situation and incorrectly relating events and likelihoods to past experiences and irrelevant events perceived to be similar. To overcome these pitfalls in assessing probabilities for risky decisions, Hardaker et al. (1997) advocated facilitating subjective probabilities for decision-making by using experts, experiments, past experience, and simulation. All these sources can be used to derive subjective probabilities of exotic disease occurrence on farms. This information could serve as the foundation for farm disease risk information programmes.

At the farm level, risk management strategies can be categorised as collecting information, avoiding risk, selecting less risky practices, diversification, flexibility, and insurance. All these strategies may have relevance to farm animal disease management and information plays a key role as it can help reduce the dispersion of the subjective probability distribution. Information can shift the location of the distribution. Thus, better information on the presence, spread and consequences of disease can facilitate better decisions. Avoiding or reducing exposure to risks includes such potential actions as postponing a decision until more information is available, implementing safety standards until more is known, or taking a decision that is close to the status quo. With respect to farm disease, this might include taking preventive measures prior to confirmation of outbreaks in the area. Selecting less risky practices, such as maintaining a closed herd, would minimise risks of some diseases. Diversification might have less direct relevance to farm animal disease, but one might imagine that diversified farms might be better equipped to deal with consequential losses. Finally, flexibility refers to maintaining options that allow for more responses to risky situations.

Risk aversion and uncertainty

All producers are likely to make certain investments in disease prevention, but their management decisions under risk depend on risk aversion. Rat-Aspert and Fourichon (2010), using a decision-epidemiologic model, found that more risk-averse producers make greater efforts to prevent disease to reduce the probability of such an event, which in turn would lead to lower disease occurrence. Niemi and Heikkila (2011) concluded that a risk-averse producer may be willing to pay advance premiums to reduce unpredictability of disease losses, whereas a risk-neutral producer does not pay attention to the volatility of losses. Risk-neutral producers prefer a financing scheme which collects funds only after an outbreak has occurred, whereas risk-averse producers prefer a scheme which collects premiums both before and after an outbreak.

While it is common to use the concepts of risk and uncertainly interchangeably, economics differentiates between the two. Risk refers to situations where potential states or outcomes are known, along with the probability of their occurring. Uncertainty may be defined as not knowing or having no reasonable approximation of either the outcomes or the probabilities of the event occurring (Hardaker et al, 1997; Mahul and Gohin, 1999). Uncertainty leads to option value and information value literature. Bernanke (1980) notes that uncertainty retards investment. Greiner et al. (2009) analysed the adoption of best conservation practices by farmers and found that option values for unknown events prevented strongly financially motivated farmers from adopting new practices in the absence of external incentives. In the context of livestock disease management where farmers decide whether to invest in biosecurity, the cost of deferred biosecurity is lost output, while the gain is additional information. Bloom (2014) found that uncertainty increases in times of economic downturns. Does risk perception increase during disease outbreak? It seems likely. It is therefore worth considering farmer responses during an outbreak as being different than in "peacetime" with respect to a specific disease.

Elbakidze and McCarl (2006) compared pre-event preparedness *versus* post-event response and asked when it would be economical to protect from infection. Specifically, they highlighted the trade-off between certain pre-event (*ex ante*) expenses for probabilistic events and expenses after (*ex post*) an infectious disease event. For these diseases the probabilities are generally unknown and subject to lack of information and context. They found that the optimal level of investment in pre-event preparedness would increase as an event probability and severity becomes larger and post-event response strategy is less effective and more costly. For potentially low probability of infection, marginal benefits of *ex ante* biosecurity might be quite small. Also, if there are neighbouring farm operations which are not investing in biosecurity or there are wildlife reservoirs nearby, the farmer may believe (justifiably) that their efforts are unlikely to have a significant impact. Thus, one expects farmers to under-invest in prevention of these diseases.

For insurance related to livestock disease – either explicit insurance such as business interruption or implicit insurance such as *ad hoc* compensation schemes—an important issue is the extent to which it can influence farm behaviour. A particular concern is that the presence of insurance may encourage riskier behaviour from farm managers relative to disease management. A risk-averse farmer will reduce the expected financial impact of a loss by reducing the severity of any loss that occurs (self-insurance) and by reducing the probability of loss occurrence (self-protection). Ehrlich and Becker (1972) showed that self-insurance is always a substitute for market insurance, whereas self-protection and market insurance might be complements. OECD (2011) indicates that crop insurance produces a crowding-out effect on production diversification as an on-farm risk management strategy and that farm income has greater variability with a higher share of insured land.

2.3. Farm incentives and information asymmetries

- Information asymmetries exist with respect to farmer actions and risk types.
- Higher indemnities can strengthen the incentive to report, but weaken the incentive to prevent disease.
- There is a lack of empirical studies to verify the predictions from analytical models in this area, but some empirical evidence finds that disease reporting is "price-elastic" in relation to the indemnity received.
- To align incentives with policy goals, any indemnity plan should shift part of the risk to farmers.
- Insurance for interruptions in farm business may increase incentives to report, but is difficult to put into place.

Animal disease management as a principal-agent contract with hidden information

There is a relationship between governments and farmers or livestock industries in preventing and controlling livestock disease. Governments control borders, negotiate trade agreements, and establish eradication and surveillance programmes. Farmers are responsible for their own herd health management and must disclose reportable diseases. For many contagious diseases, particularly those with human health or trade implications, the government will purchase condemned animals as a form of indemnity. Such compensation can also involve further assistance to clean and disinfect farms, or even payments for consequential losses (e.g. business interruption).

These relationships between farmers and government might be thought of in terms of a contract (Gramig et al., 2009; Hennessy and Wolf, 2015). Theoretically, this contract foresees that the farmer will make an adequate effort to prevent disease or – failing that – report the presence of disease, while the government will make efforts to prevent the introduction of the disease, provide surveillance at and within country borders, and organise responses should a disease occur.

A principal-agent framework applied to government-paid indemnities to farmers for diseased livestock can be set up as a government principal wishing to minimise expected disease costs, subject to getting farmers to invest appropriate efforts into disease prevention and control. There are many instances where farmers might have relevant information about disease in his herd, as well as information about their efforts to prevent disease (the likelihood of disease) that are unknown to the government. This can create two types of information problems: moral hazard and adverse selection.

Moral hazard refers to a situation where the agent(s) can undertake actions that affect the value of the transaction with the principal but that the principal cannot monitor or enforce perfectly. If the agent can put in less effort without detection – and less effort decreases the likelihood of a desirable outcome – then one would expect shirking on the part of the agent. That is, if others are willing to pay for mistakes you make, then you are less likely to consider the negative repercussions of your behaviour. The solution might be to make the potential farm loss under disease – that part which is not covered by indemnities – significant enough so that the farmer has an incentive to put time and effort into an effective biosecurity action.

Adverse selection applies to situations where the agent has information pertaining to a relevant transaction but which is unknown to the principal. With respect to insurance, this may lead to customers who are at a relatively high risk *vis-à-vis* others to be relatively well insured (Baltussen et al., 2006). Adverse selection leads to the crowding out of low-risk customers by those who are at high risk, leading to a potential failure of the insurance market. The solution to adverse selection in insurance has been to structure the set of contracts available so that the customers' choice of contract terms signals their risk profile (i.e. high or low risk).

Adverse selection may occur with respect to reporting disease and epidemic indemnification. If the farmer reports a disease, he will incur costs related to that reporting. If the farmer perceives, perhaps incorrectly, that the expected costs are smaller when disease is not reported, one can expect that behaviour to occur. Although most informed farmers would report the disease, in the case of highly contagious diseases, significant economic damage can occur with only a few bad outcomes, even just one (Hennessy and Wolf, 2015). For example, Enright and Kao (2015) using a game-theoretic simulation, suggest that even a small number of non-cooperating farms could make a difference in the prevalence of disease, with this contribution becoming greater if the disease is easily transmissible.

Private costs and economic incentives for disease reporting

The farmer is expected to maximise net profits (or utility as a function of expected profits) by choosing appropriate disease prevention and control practices. A standard optimisation results in a first order condition that equates the decline in marginal expected loss from disease to the marginal cost of control measures (McInerney, 1996; Chi et al., 2002). The decline in expected losses is a benefit from farmers' efforts to manage disease. It may include a lower probability of many diseases on the farm which may also spill-over to benefit neighbours by reducing the incidence of disease on their farms; it may also reduce the possibility of wildlife disease and risks to human health. The desired behaviour is that the farmer should report the disease quickly to limit its spread.

The consequences for an individual farmer of reporting disease, however, provide many disincentives to report. If the animal has a disease for which there is mandatory control or eradication programmes, the herd or flock will be depopulated. This results in lost genetics, potentially lost capital value (depending on indemnity payments relative to actual market value), and losses from business interruption as fixed costs must be covered. In addition, depending on the disease, other herds in the region or even the entire country might be subject to quarantine or movement restrictions. These restrictions result in losses for other herds and perhaps even an entire industry. The slightest suspicion of a diseased animal can shut down international trade for some diseases, e.g. bovine spongiform encephalopathy. The potential for consumers to associate – perhaps incorrectly – human health risks with the presence of disease can result in reduced demand. For diseases with mandatory control and eradication programmes, government and media scrutiny is also unpleasant and potentially costly. Thus, the farmer may be inclined to respond by waiting to see if recovery is possible, quickly marketing the suspect animal, or destroying the animal without alerting the authorities.

The amount required to incentivise reporting is a function of current market conditions and a number of potentially farm-specific factors, but several considerations can frame the problem. In order to align incentives, farmers must be compensated for reporting at least as well as they would be in the next best alternative. For example, if the farmer believes the alternative is to quickly market the animal and avoid business interruption, then the indemnity must be at least at the level that can be achieved on the market. Should depopulation be needed and the farmer to abstain from livestock production for a quarantine period, then business interruption is a relevant consideration for the farmer. Losses from business interruptions include foregone revenues net of avoided costs. To understand business interruption losses, a distinction between variable and fixed costs is useful. When a cattle enterprise is removed, many – and perhaps most – variable costs of production are not incurred. For example, there is no need to purchase feed for cattle. Fixed costs, in contrast, cannot be avoided or varied when production ceases (over the time period considered). The standard list of fixed costs includes interest on investment, depreciation, property taxes, and insurance. Because the depopulated farms are expected to resume operation, the fixed costs must be covered during the interim period.

Finally, the study by Sheriff and Osgood (2010) is interesting in that it adds a temporal perspective, suggesting that incentive compatibility constraint is more restrictive in the multi-period model than in a single period model. By revealing disease exposure today, sellers of livestock signal a higher chance of future exposure. If they believe the buyer will use this information against them, sellers with unhealthy animals must be compensated for future income loss in order to be willing to truthfully reveal disease today.

Compensation effects on disease prevention and reporting

Barnes et al. (2015) undertook a comprehensive review of the literature related to the effect of animal health compensation on farmer disease prevention and reporting. They note that economic insights into this issue are largely based on theoretical or simulation modelling that use stylised situations and simplifying assumptions rather than empirical data (e.g. Jin and McCarl, 2006; Beach et al., 2007a; Hennessy, 2007a; Gramig et al., 2009; Boni et al., 2013; and Hennessy and Wang, 2013). They also conclude that there is a general lack of comparative evaluations based on actual rather than modelled outcomes under different policies.

The basic premise of economic analysis is that all else being constant, the higher the indemnity the greater the likelihood of disease reporting. While compensation encourages reporting, it can also reduce the privately optimal preventive investment (Beach et al., 2007b). Hennessy (2007a) and Hennessy and Wang (2013) find that indemnity payments are likely to reduce producer incentives to protect herds, as do Bicknell et al. (1999). Beach et al. (2007a) found that there was a bigger deviation between private and social optima in regions with greater disease externalities and smaller farms, especially when high compensation was independent of preventive actions.

The study by Kuchler and Hamm (2000) is notable in that it examined 41 years of experience with indemnities as a natural experiment on the incentives created by prices. They studied US farmers reporting of sheep infected with scrapie, a prion disease for which the US government had an indemnity-based eradication programme from 1952 through 1992. It was then replaced by a voluntary flock certification programme. The authors recognised the potential for moral hazard as farmers could essentially manufacture diseased animals if it was profitable to do so. While the market price for sheep moved in response to supply and demand, the indemnity payment was fixed. Relative prices are important in this case and when the fixed indemnity was higher than the market price for sheep, farmers "produced" or found more diseased animals. Similarly, when the indemnity was lower relative to market price, fewer animals were turned in for indemnity. The authors found that not only was the supply of diseased animals upward sloping, but that it was price elastic, i.e. a 1% increase in indemnity payments relative to the market price for lambs yielded a greater than 1% increase in the number of confirmed scrapie cases.

The further logic is that compensation can provide adequate incentives to producers to prevent and report disease if it is designed to account for moral hazard and adverse selection problems. Within this logic, design characteristics of compensation, such as eligibility criteria, payment rates and schedules become essential. The basic principle is that farmers should share risks (and costs) of disease epidemics. Full compensation will not encourage preventive behaviour; indeed, "why bother if all costs are covered?" (Gramig et al., 2009; OECD, 2012; Barnes et al., 2015).

Gramig et al. (2009) suggest an indemnity scenario to deal with both moral hazard and adverse selection problems. A farmer's investment in biosecurity is modelled as an *ex ante* moral hazard problem and farm reporting as *ex post* adverse selection. The authors argue that a one-size-fits-all indemnity payment cannot deal with both information problems. Two distinct mechanisms are needed for each: an indemnity to address moral hazard and help achieve the desired levels of biosecurity, and fines to induce early disclosure of disease status and address adverse selection problem. By combining two distinct policy instruments, each designed to deal with a single information problem, it is possible to create incentives for farmers to behave consistently with government objectives. Comparing this to a simple indemnity reveals an important difference: while standard indemnities increase with disease prevalence in a herd (i.e. pay the farmer for each diseased animal), the solution here is that the indemnity decreases over a range of disease prevalence which reflects how long the disease was present on the farm before it was reported. This scenario represents a differential indemnity schedule based on reporting the disease and employing the deductible principle in order to shift some of the risk to farmers.[3]

Hennessy and Wolf (2015) further develop that if the costs of reporting depend on market, industry, and farm specific factors, behaviour will depend to some degree on those factors. For example, if reporting results in an indemnity payment that is set at an average market price, one might expect farms with inferior quality livestock to be more amenable to reporting than those farms with superior quality livestock. Similarly, if reporting results in mandatory depopulation and business interruption, one might expect that those farms with relatively higher fixed costs (which must be borne during business interruption) to be more reticent to report than those with lower fixed costs (Wolf, 2005).

Making indemnities contingent upon farmer reporting assumes that a reasonable manager would and could notice the disease, so this condition makes more sense for diseases with readily identifiable symptoms. Livestock disease control systems are often based on ways of detection which expand vulnerability. First, detection often uses visual observation of clinical signs; thus disease can be present and spreading before detection. Second, the clinical signs of some important (dangerous) diseases are indistinguishable from signs of other diseases and could be misidentified (Bates et al., 2003; Elbakidze, 2008). Studies reveal that farmers, and sometimes even veterinarians, experience difficulty in identifying reportable diseases (Box 2.1).

Farmer incentives for disease prevention could be increased if indemnities are made conditional on farmers exercising certain biosecurity practices, implementing farm biosecurity plans, or participating in disease programmes. This, however, imposes high monitoring efforts on governments, but country experiences show that this effort could be shared with or performed by industry groups (Chapter 5)). Another way to address incentives for prevention is to differentiate indemnities according to farmer risk profiles, for example, the disease outbreak history of the farm (Chapter 7). Meuwissen et al. (2006) also considered that classifying farms based on their epidemic disease risk and use of deductibles was important in order to align incentives with policy goals. This approach is also demanding in terms of administration: beyond the challenge of defining the risk status and differentiating farms accordingly, it requires the establishment of the relevant information systems.

Consequential losses are typically outside the scope of compensation schemes for epidemics and regarded as entrepreneurial risk. Some of these losses are a consequence of compulsory measures to control the epidemics, such as protective vaccination[4] and livestock movement restrictions. Consequential losses influence the farmers' incentives to disclose a disease as they have strong implications for the longer-term operation of farms.

Livestock insurance may be one solution to market risks related to livestock epidemics (Meuwissen et al., 2000; Meuwissen et al., 2006; Meuwissen and Asseldonk, 2013). However, such insurance is in practice limited because of the significant difficulty to estimate the scale and probability of livestock epidemics risk, classify and price it accordingly, and because this risk tends to be systemic. As a result, the actual supply of livestock insurance is limited, while its uptake from producers is low due to high premium costs. This may indicate a market failure in provision of livestock disease insurance and can be an argument for a policy action (e.g. creation of information systems to facilitate the 'production' of insurance products) to make such insurance more operational. Other market instruments to manage livestock price risks are forward-, futures- and options contracts, but the degree to which these can deal with prolonged market effects is unclear, while only limited groups of livestock producers use futures and options contracts. There exist industry risk pooling arrangements, such as industry funds, but they are rare and typically created to deal with direct epidemic losses. Thus, the approach to consequential market losses from disease epidemics remains a largely open policy issue.

Financial considerations are not the only drivers of farmer reporting behaviour. Farmers may experience difficulty in identifying a reportable disease, dissatisfaction with, limited awareness, or uncertainty about reporting procedures, farmers may also feel guilt and shame about reporting a disease. These aspects are the focus of Chapter 3 which draws on the behavioural literature. It is nevertheless important to stress here the complexity of farmer reporting behaviour (Box 2.1).

In this respect, Barnes et al. (2015) observe that the economic literature concentrates on financial incentives, while the behavioural literature is mostly concerned with non-financial drivers. These two research streams are weakly integrated and there remains scope for investigating the extent to which the performance of compensation arrangements might depend on behavioural influences. The suggestion by Elbers et al. (2010b) well exemplifies the problem – they point out that increasing compensation may be ineffective as a means of encouraging reporting if a disease is not perceived by farmers as a serious problem. Here they notice the interaction between a financial incentive and behavioural driver such as farmer's risk perception. Thus, a range of financial, regulatory and nudging policies are required to match farm response with socially desired outcomes, although empirical and theoretical evidence to discern the optimal mix of interventions is limited.

Box 2.1. Non-financial determinants of farmer-reporting behaviour

Producers' level of knowledge about diseases and their likely consequences informs their risk assessment and responses. The inability to identify clinical signs of disease quickly, or to identify the signs which need to be reported and at what threshold, hampers reporting (Wright et al., 2016; Delgado et al., 2014; Elbers et al., 2010a).[1] The situation may be further complicated if there have been no disease occurrences in a long time, so both producers and veterinarians may not be prepared to quickly identify disease (Elbers et al., 2010b). This could be coupled with the fact that some farmers (and veterinarians) feel that raising a false alarm would be worse than missing a possible emergency (Elbers et al., 2010a; Elbers et al., 2010b). Producers' beliefs about the extent to which they can efficiently control the event may also determine behaviour. Those who feel they can themselves control the outbreak do not tend to report it immediately (Wright et al., 2016).

Risk perceptions are a factor in farmers' reporting behaviour (Wright et al., 2016; Elbers et al., 2010; Delgado et al., 2014). For example, Bronner et al. (2014) studied the brucellosis surveillance system in France based on mandatory notification of bovine abortions. They note that despite the epidemiological rationale to detect a brucellosis outbreak early, most farmers viewed it as an externally-imposed tool concerning an externally-imposed issue that created few worries for them.

The behavioural literature reveals that community opinions influence farmer reporting behaviour. Some sources refer to guilt and shame and "farmer stigma" related to disclosures of disease.[2] Farmers may feel that if they report, in particular if they are the first to do so, they will be negatively viewed by their social network (Elbers et al., 2010b; Delgado et al., 2014). A cross-country study by Vergne et al. (2016) showed that farmers and hunters who did not immediately report suspected cases of disease were more likely to believe their reputation in the local community would be adversely affected if they were to report. However, social influence can also be propulsive to reporting if this constitutes an existing social norm, i.e. if farmers believe that the persons whose opinion matters for them expect them to report and that others would also report if disease occurs on their farms. Delgado et al.,(2014) find, for example, that US cattle producers indicated they would experience social pressure from all the external groups included in the survey (e.g. family, veterinarians, business partners, neighbours, professional organisations) to report cattle with clinical signs consistent with FMD.

Box 2.1. Non-financial determinants of farmer-reporting behaviour (*cont.*)

The transactions costs of disease reporting appear to be a significant factor. Dissatisfaction with procedures – "long and tedious", not transparent, or leaving uncertainty about the outcomes of reporting – are found to be among the deterring factors (Elbers et al., 2010b). Delgado et al. (2014) observed that any uncertainty associated with compensation was likely to influence producers' willingness both to report disease and comply with response measures. Some surveillance actions based on disease notification can be seen by farmers as time-consuming, impractical or compensating for bureaucrats who are not doing their part (Gunn et al., 2008). Consideration of costs and benefits of investigating clinical signs of disease is also identified as a factor of producers' reporting decision-making: if an animal is worth less than the cost of veterinary service, it makes more economic sense to kill it than pay for a veterinarian visit. The service infrastructure, e.g. proximity of a veterinarian, has been identified as a factor in the reporting disease by Australian farmers (Wright et al., 2016).

The general acceptance of reporting frameworks, a sense of ownership of the rules, and overall trust in government play a role in the reporting behaviour of farmers. Although farmers expect to cede some of their autonomy for improved biosecurity, they can feel frustrated at the prospect of losing control of their business if a disease is identified on their property (Wright et al., 2016). Farmers may view control measures as inappropriate and be unwilling to comply with them (Elbers et al., 2010b; Bronner et al., 2014)[3]. Trust-building, involvement in decision-making regarding surveillance and reporting frameworks, a two-way and clear communication about future actions would help increase collaborative behaviour with producers (Wright et al., 2016).

1. The study of Dutch farmers by Elbers et al. (2007) showed that Dutch pig farmers had limited knowledge of clinical signs of classical swine fever (CSF): 33% of pig farmers could mention at maximum three clinical signs associated with this disease (all in the late stages of this disease) and 7% were not able to mention a single clinical sign and said they were entirely dependent on the veterinary practitioners' ability to judge a clinically suspect situation. The study by Delgado et al. (2014) of cow-calf producers in Texas showed that less than 20% of respondents strongly agreed they knew the clinical signs associated with serious cattle diseases such as FMD, and less than 30% strongly agreed they knew which cattle were at greater risk of disease introduction.

2. For example, a representative of the Australian Meat and Livestock Association notes that "producers are often reluctant to report disease on their properties for a variety of reasons. In some cases certain diseases create a certain amount of stigma in society. I've been in a situation where a farmer was acutely embarrassed when a certain parasite was diagnosed in his sheep, and he was too ashamed to show his face in the local town for months afterwards" (ABS Rural, 2016).

3. For example, in the Netherlands, specific rules were set on reporting an AI-suspect situation after the epidemic of highly pathogenic avian influenza in 2003. According to Elbers et al. (2010b), poultry farmers indicated that they did not agree with these rules. Farmers did not see why they should report clinical signs that they interpret as being linked to other diseases or other causes. The authors state this is an indication of a lack of ownership of the surveillance system on the part of the poultry farmers.

2.4. Farm size, industry structure and spatial issues

- Industrialised production can be associated with increased disease prevention and control efforts, but also with large impacts of disease if it breaks out.
- Hobby/lifestyle residential farms are likely to be more motivated by factors other than financial.
- Hobby producers are likely to underinvest in biosecurity because they do not consider effects of disease on professional producers.
- Policies designed with consideration of commercial farms only are likely to be a poor fit for non-commercial operations.
- Biosecurity efforts of neighbours affect producer incentives to prevent and control disease.

While the proportion of livestock, dairy and poultry products from large, commercial operations has increased over time, smaller operations exist in the form of part-time, hobby, life-style farms, and, in some countries, as subsistence farming segments. There are many ways to divide or segment farms by type based on the motivation of their operator. Primary motivations include business, such as profit and equity, but also family values, lifestyle, and hobbies. While specific categories depend on the context and method of analysis, it is clear that those who make decisions within farm enterprises vary in their mix of values and motivations that drive their decisions, including those related to disease control and prevention. It should also be noted that in addition to farm livestock, pets and other backyard animals can affect disease occurrence and spread. This section considers the implications for disease management from this diverse set of farming structures. It concludes with the discussion of spatial issues of disease management.

Industrialised agriculture

With changes in technology, reform of long-time agricultural support policies, and the subsequent integration into world markets, livestock agriculture has undergone significant structural change. Commercial farms are becoming larger and more specialised. The prototypical example is contracting in the US poultry and pork industries where large corporations own the livestock which are raised by contracted farmers. This leads to important disease management and liability questions. Disease prevention and control is expected to depend on farm size, available resources and production technology, all of which are jointly determined (Hennessy et al., 2005; Hennessy, 2005).

As livestock operations increase in size, production technology usually dictates a movement towards confinement operations. Animals spend less energy on foraging, defence against predators, and temperature regulation (Wang and Hennessy, 2014). Confining animals also involves physical protection against infection and other diseases. Therefore, the animals' environment is under greater control. At the same time, control technologies are also required as animal and or farm density can be a factor in increased disease risk.

How do incentives to guard against infectious disease risk interact with the scale of production? There should be scale economies in biosecurity, at least in investment in facilities and enclosures. Siekkinen et al. (2012) studied the cost of biosecurity on Finnish poultry farms. They found economies of scale, i.e. costs decreased as size (number of birds) increased. This effect was largely driven by decreasing labour costs. However, Wang and Hennessy (2014) found that because biosecurity is a technical complement to scale, a unit cost decline in biosecurity can reduce optimal scale.

Larger commercial operations (poultry or pig meat) are less likely to become infected because of their larger resources and more stringent biosecurity measures; see for example Beach et al. (2007b) who analyse highly pathogenic avian influenza. However, to the extent that infections do occur in these sectors, the impact is likely to be very large, with many animals killed by disease and depopulated. Mintiens et al. (2003) considered risk of classical swine fever (CSF) spread in Belgium and concluded that densely populated livestock areas incorporate an increased risk for epidemic disease spread when outbreaks occur. Rushton (2009) noted that large, industrial livestock operations might capture most of the benefits of livestock disease control and eradication. In general, one would expect increased biosecurity and therefore less potential for disease outbreaks on very large operations because of the level of investment and specialisation of these operations.

Part-time, hobby or lifestyle residential operations and backyard flocks

The risk factors associated with small (backyard) production include reduced hygiene and biosecurity measures, a mixed confinement which increases the probability of disease transmission across species, and free range allowing the interface with wild life (e.g. Whitehead and Roberts, 2014; Conan et al., 2012; Hamilton-West et al., 2012). Other authors highlight the features of small-scale production which may reduce disease risks, such as extensive free-range systems, which in this argumentation is a factor preventing rapid disease spread, spatial dispersion of small producers, and the fact that animals in small establishments may have a more mobilised immune system due to exposure to diverse environmental stress (Behnke et al., 2011).

As far as developing countries are concerned, smallholders are generally viewed as the major weak point in national biosecurity (Grace et al., 2008). As for developed economies, the evidence about the role of smallholdings in the occurrence and transmission of disease is fragmented. This issue has attracted increased attention in recent years in the context of the outbreaks of highly pathogenic avian influenza. Bavinck et al. (2009) found that from an epidemiological point of view, backyard flocks played only a marginal role in the outbreak of the highly pathogenic avian influenza in the Netherlands in 2003. Smith and Dunipace (2011) estimated that the contribution of backyard poultry flocks to the transmission dynamics of highly pathogenic avian influenza epidemics in commercial flocks was "modest at best". However, they also warned against ignoring the contribution of backyard flocks in estimating the efforts to control the disease. Beach et al. (2007b) observe that minimal biosecurity present in nonindustrial production is frequently identified by animal health agencies as a risk to commercial sectors, even in countries where these activities account for a negligible share of output and sales. Conan et al. (2012) present the view that neither system is more to blame for infectious disease spread and that biosecurity levels have to be increased in both commercial and backyard poultry systems.

Understanding the incentives of small holders to protect their livestock is important for the development of policy approaches towards these constituencies. Part-time, hobby or life-style farmers do not depend significantly on agricultural enterprises for their income. Thus, the financial implications of disease may not motivate them to invest in biosecurity measures (Defra, 2008).

Kobayashi and Melkonyan (2011) found that biosecurity actions with own benefits or lasting impact in home communities exhibited a positive relationship with the behaviour of producers from geographically close areas. The number of biosecurity actions taken were positively associated with the number of animals, and varied among commercial and hobby producers and across species and types of commercial production.

Professional farmers have incentives to carefully monitor and manage biosecurity, while hobby farmers derive utility from the value of the farming activity itself (Blank, 2005; Defra, 2008). Ceddia et al. (2008) considered biosecurity in application to invasive crop species by comparing profit-seeking professional producers to utility-seeking hobby producers. Hobby producers are likely to underinvest in biosecurity because they do not take into account the effects of disease on professional producers. Since disease control generates positive external benefits, hobby producers will under-invest in it. While the gains from a socially optimal policy are sizeable, the transactions costs of a corrective policy may be prohibitively high. A pest control subsidy for hobby producers can lead to an increase in hobby production with associated negative impacts. This subsidy also would not recognise that the mere existence of the hobby farms is an important component of the problem. An alternative is a penalty for hobby farms based on the deviation of their pest control from the socially optimal level. However, this would be hardly realistic as it requires monitoring and large transactions costs. Finally, professional and hobby farmers could get together to have a joint surveillance and control programme. The policy implications of this work are that designing policies with commercial farms in mind is likely to be a poor fit for the non-commercial operations. These groups seem to be logical candidates for voluntary assurance and co-operative programmes.

Spatial aspects

The spatial analysis provides insights into how externalities affect farmer's incentives for disease management. Locational characteristics lead to heterogeneity of producer incentives to prevent and control disease, they affect the degree to which producers are both vulnerable to risk and can free-ride on the biosecurity efforts of others (Horan et al., 2010).

Hennessy (2007b) studied spatial externalities of disease across multiple operations in close proximity. He used an illustrative model of agricultural biosecurity where only farm location and production scale were articulated. The author concludes that the nature of spatial interactions matters as it determines the extent of incentives to free-ride on neighbours' actions. For instance, "edge" farmers (with neighbours only on one side) face lower risks than "middle" farmers located in-between two neighbours. The middle farmers thus would invest more in biosecurity, whereas edge farmers may free-ride on these efforts. Another observation is that intensive production, by strengthening private incentives to protect, can reduce the proportion of potential production lost to disease in a region. However, subsidies targeted to smaller production lots may encourage larger farms to invest less in biosecurity, thus reducing the overall economic surplus.

Rat-Aspert and Krebs (2012) examined the collective action to control endemic diseases for which management decisions are left to individual initiative. In their model a farmer decides whether to protect his herd against a particular disease by vaccinating or by adopting biosecurity measures which create a positive spill-over. By lowering the risk of disease occurrence, this would provide benefit to other farmers. Conversely, farmers could be encouraged to behave as a free-rider seeking to benefit from the efforts of neighbours without bearing the costs. This behaviour would generate a negative externality since this behaviour would lead to maintaining the disease within the geographic area considered. This results in strong interrelationships of individual decisions to control animal disease at the area level. For communicable diseases, effectiveness of control measures will often depend on the ability to act in a coordinated manner across a group of operations (horizontal coordination).

Rich et al. (2005a, b) analysed the decisions to control foot-and-mouth disease (FMD) as a spatial model in which behaviour of neighbours influences the payoffs to each individual from control efforts.[5] Producers could choose between high and low effort to control FMD. Low effort results in contracting the disease with certainty. Because of disease spill-overs, the effectiveness of high effort depends on the actions of neighbours. In locations with high prevalence of disease, the rationale to increase control of disease is relatively low, while spatial spill-overs only exacerbate the problem with the result that disease is likely to be endemic. In locations with lower disease prevalence, producers may be more or less inclined to engage in increased disease control depending on neighbours' choices. The authors suggest that for disease control regulation to be effective, private incentives across space need to be aligned and argue for a spatially nuanced policy depending on risk factors and pay offs to biosecurity. Beyond that, policies that promote market development and increase the herd value may be the most effective as they increase private incentives to prevent and control disease.

2.5. Implications for animal disease policy

This chapter framed the farm management decision by focusing on economic and financial aspects of disease management. It can be expected that individual farmers will under-invest in prevention and control as the market does not reflect all costs or all benefits for farm-level disease management. Farmers may also see returns to investment to be better in other areas and value short-term gains more than possible larger long-term gains from investments in farm biosecurity. In this situation farm managers may not be incentivised to behave as policy makers would prefer them to do when making animal disease management decisions. Thus, policy makers must consider actions to more closely align the public and private costs and benefits of such practices. Several areas of public action for reducing the divergence between private and socially optimal outcomes might be justified, especially as some diseases have large social economic costs.

A rational economic decision process assumes that a profit-maximising farmer will invest in prevention up to the point where the marginal private benefit from prevention is equal to marginal costs. Farmers' biosecurity effort thus derives from weighing the costs against benefits of such effort. The trade-offs depend on the nature of the disease, available techniques, the costs involved, market conditions, and other factors. Producer must understand these trade-offs, so knowledge and information is an essential input into individual's biosecurity decisions. The less aware farmer is likely to make inadequate investment decision to prevent disease and this will determine the overall risk of disease entry. The policy role in this regard is to assist farmers in gaining the relevant knowledge, including by tailoring the information to farmers' particular needs and circumstances and providing them with decision-support tools. Development of technologies and services that lower prevention and control costs is an additional area for public action, for example, expenditures to reduce cost and efficacy of disease tests and veterinary services might be in order. Within the basic economic framework, these investments would shift a private loss-expenditure frontier so that private cost-benefit solution would result in less disease.

Economies of scope in biosecurity practices are generally ignored which undervalues these practices. When disease management is considered at the farm level on a disease-by-disease basis, the cost-benefit can be misleading. Often management practices that prevent or eliminate one disease assist in preventing or eliminating many others. Thus, disease prevention and management may exhibit economies of scope. The consideration of potential preventive spill-overs in disease education and information programmes can encourage farmers to take these effects into account in allocating effort and investment to disease prevention and control. Farm level decision tools and aids should account for these benefits. The potential for realising these gains should be actively communicated to farm managers as part of disease risk communication and advice for farm biosecurity practices. Understanding that practices prevent many diseases will strengthen farm incentives to undertake those practices.

Uncertainties and risks are associated with virtually every aspect of disease management, making farmers' risk perceptions important drivers of their decisions. If a farmer wrongly perceives the risk to contract disease on his farm to be negligible, he is unlikely to invest in its prevention. Furthermore, farmers need to understand the probability of disease to optimise investment in disease prevention. There are biases and risk perception issues that must be overcome for farm managers to make appropriate livestock disease management decisions. Thus, governments should facilitate animal disease risk communication, information, and education so that farmers build understanding about their own risks and the links between individual preventive efforts and outcomes for the sector as whole. On the other hand, to design effective policy governments need to understand the risk awareness and risk preferences of farming constituency. For example, the effectiveness of disease reporting frameworks may depend on farmer's perception of associated risk. Despite the fact that the issue of farming risk is increasingly featured in the governments' policy agendas, there is a continued lack of evidence on farmer individual risk perceptions and preferences.

Public policy intervention in livestock disease management can directly impact producer decisions. Diseases where human health is at risk or which have large potential economic effects associated with them are in the domain of public control. Public policies here range from bounties/indemnities for infected livestock to required herd depopulation and farm decontamination.

Farmer actions and relevant information about the farmer and farm operation are not perfectly observable. The presence of information asymmetries related to monitoring behaviour in preventing and reacting to disease outbreaks created an additional challenge for aligning incentives for disease prevention and reporting.

Higher indemnity payments can encourage farmers to monitor and report diseased animals by compensating for the losses in animal value taken for disease eradication. This is particularly appropriate for diseases where timely detection is crucial to minimise damages to the industry, economy or human health. Paying fair disease-free market value is necessarily greater than the true market value of diseased animals culled by the government. This action is often justified as intending to create incentives to report. However, one must be mindful not to provide incentives for farmers to produce diseased livestock. Several natural experiments have confirmed that misalignments in reactions to financial policy incentives occur. Higher indemnity payments can discourage farmers from biosecurity measures to limit the possibility of disease occurrence and spread. If someone else is paying for losses there is less incentive to avoid risky behaviour. A critical aspect of livestock disease policy is to avoid the perverse incentive to produce infected animals.

Animal health authorities have typically relied on a single mechanism – indemnities – to facilitate both *ex ante* biosecurity effort and *ex post* reporting. By using a single mechanism to promote biosecurity and to report simultaneously, the incentives for individual private action are not clear.

Unless farmers face some uncompensated losses as a result of outbreak it cannot be expected that they undertake sufficient prevention and timely report disease. Some countries have implemented policies which move towards risk-sharing in interesting and appropriate ways. For example, if there is no indemnity for dead animals there may be a penalty for waiting to report disease. This policy can help to achieve incentive compatibility with reduced or eliminated monitoring costs. Some of the risk would shift to farmers if the indemnity rate decreases over some range of disease prevalence, or if partial compensation for already-infected animals is provided. An indemnity plan that does not shift risk in this way may actually create incentives for infection.

Furthermore, farmers react to private incentives and the best course of action for an individual farmer will depend on the farm type and size as well as individual financial considerations. For example, one might expect farmers to react differently to the same indemnity rate depending on the individual costs they incur: e.g. farms with superior quality livestock and higher fixed costs would be more reticent to report disease than those with lower quality animals and lower fixed costs. Economic modelling may be instrumental to evaluate how different farmer groups, regions, and market segments respond to the size of incentives.

In deciding whether to report disease, farmers react not only to financial incentives. The ability to identify reportable disease, transactions costs and uncertainties associated with reporting, psychological barriers, social pressure, acceptance of reporting regulations and overall trust in government, also influence the disease disclosure. The degree to which financial and non-financial drivers interact and impact farmer decisions is little researched. Building a holistic view of barriers to disease reporting is a necessary step towards more effective and cost-efficient disease control frameworks. Some countries have progressed in this direction (Chapter 5).

Diverging farm size and specialisation has implications for farm management and policy. Farm size and type are correlated with incentives and behaviour related to livestock disease management. Large, industrialised farms have significant investments in livestock and are more likely than smaller operations to have accompanying disease management systems. The production technology that complements biosecurity practices is more likely to be present on full-time operations. They are also more likely to have full time veterinary services. However, the magnitude of a disease outbreak is also much larger should prevention or containment fail. Part-time and hobby farms may be less aware of disease issues and practices. Keepers of backyard flocks are even less likely to be concerned with disease prevention. Smaller operations may also be less responsive to financial incentives than larger commercial operations. The existence of part-time or hobby farms alongside commercial livestock operations is important because they are less likely to be motivated by consequences to profit or assets from disease outbreaks. To incentivise these groups for increased disease prevention and reporting, a local action is likely required. This may include voluntary surveillance initiatives, awareness campaigns, information and knowledge dissemination adapted to non-professionals, social rewards, and any other action relevant in the local contexts. The experience can be drawn from local environmental initiatives. Policy could potentially play a role in promoting and facilitating such local initiatives.

Spatial analysis demonstrates that locational characteristics lead to differentiation of farms by the degree to which they are vulnerable to risk given the biosecurity effort of neighbours. Farmers' decisions about additional investments in disease prevention are influenced by negative externalities and positive spill-overs from the actions of their neighbours and farmers may free-ride on the biosecurity efforts of others.

Appropriate disease policies, information and education programmes thus must consider the entire spectrum of livestock operations, including size, intensity and geography. To align incentives policy makers need to classify farms based on motivation, resources and constraints. Segmenting policies by farm size and type and location may also assist in aligning incentives.

Notes

1. The trade-off between losses and expenditures is shown by $L_A < L_M$ with $E_A > E_M$, and *vice versa*. Curve L(E) slopes downward at a diminishing rate, i.e. bringing losses down from L_M to L_K would require smaller additional expenditures than reducing them by the same amount from L_K to L_A, i.e. $E_K - E_M < E_A - E_M$. This is the standard economic assumption of diminishing returns. Concerning this assumption, McInerney et al. (1992) state that it has a powerful logical basis in economics and that the nature abounds in processes which display diminishing returns, so there is no reason to suppose this is different in the case of animal disease.

2. This optimum loss-expenditure combination is reached at the point when an additional unit of control cost is equated to the additional unit of reduced loss. This is the "marginal cost" criterion in economics. Graphically, the economically optimal cost of disease management (C) corresponds to the point M on Figure 2.1 where the 45° line is tangent to the L(E) frontier.

3. Gramig et al. (2009) also consider actual indemnification mechanisms in some countries that use the principle of risk-sharing. For example, Belgium and the Netherlands no longer compensate producers for dead animals in the case of epidemic livestock diseases and only partially compensate them for diseased stock. The authors note that while such a mechanism sets no explicit fine for non-reporting, there is a penalty for waiting to report since dead animals fetch no payment. This feature can help achieve incentive compatibility with reduced or no monitoring costs. Partial compensation for animals that are already infected will shift some of the risk to farmers. The authors suggest that an indemnity plan that does not shift risk in this fashion may actually create incentives to allow infections to spread.

4. Under protective vaccination, animals may not be destroyed. However, when marketed, such animals command reduced price as their processing involves higher costs.

5. In fact, this study looked at the coordination problems of FMD control across countries in South America. However, their model is neutral to whether a country or an individual producer is considered – the authors use these notions interchangeably.

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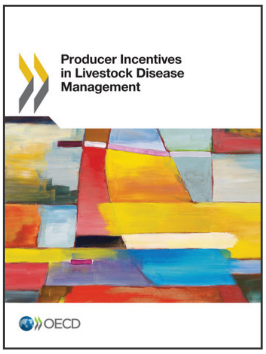

From:

Producer Incentives in Livestock Disease Management

Access the complete publication at:

https://doi.org/10.1787/9789264279483-en

Please cite this chapter as:

OECD (2017), “Economic determinants of farmer decision-making related to animal disease”, in *Producer Incentives in Livestock Disease Management*, OECD Publishing, Paris.

DOI: https://doi.org/10.1787/9789264279483-5-en

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