

Chapter 45

Economic Aspects of Zoonoses: Impact of Zoonoses on the Food Industry

Impact of Zoonoses on the Food Industry

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Abstract The increase of complexity of livestock production and the associated value chains has led to changes in the food systems that feed us, which in turn carry new challenges from zoonotic diseases in particular their impact, and the costs of surveillance, control and prevention. Direct losses to the animal and public health sectors, connected mainly to value losses due to morbidity and mortality in humans and animals, and indirect losses, such as the economic cost caused by the reaction to disease and the limiting of its negative effects, all contribute to this negative impact. Its full assessment can be challenging, but economic tools and frameworks can be used to estimate zoonotic disease impact and the economic efficiency of possible technical ways of dealing with these diseases. In this chapter, we review the impact of zoonoses across sectors, also in the context of an increasingly complex value chain, address the economic concepts behind the balance between losses due to direct costs of disease and expenditures in reaction to disease presence, and identify possible economic tools and frameworks to assess the impact of zoonoses and interventions.

45.1 Introduction

The initial successes in control of infectious diseases in animals were the control and eradication of rinderpest and contagious bovine pleuropneumonia in the late 1800s (Fisher 1998). The distribution of livestock diseases began to change more rapidly in the 1960s and 1970s as European and North American countries and Japan began to make serious inroads into the control of a range of both transboundary

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© Springer Science+Business Media Dordrecht 2015
A. Sing (ed.), *Zoonoses—Infections Affecting Humans and Animals*,
DOI 10.1007/978-94-017-9457-2_45

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and endemic animal diseases¹. This was achieved through significant investments in human skills, building on previous investments in veterinary organisations, education and infrastructure from the mid nineteenth century onwards. In the human health side attempts to manage diseases that have affected societies appear to have been in place in Europe from around the 1500s through the problems caused by the plague (Harrison 2004). The period of enlightenment expanded the knowledge of causal agents of disease (Hays 2009) and there were major breakthroughs in the control of diseases such as smallpox with the use of vaccines leading ultimately to the official eradication of the disease in 1979 (Harrison 2004). In terms of overall service delivery much work has gone into the management of human health and most countries recognise the need for coordinated health services, ultimately culminating in the recognition of the need for the International Health Regulations in 2005. These initiatives have been prompted largely by disease shocks and the core contagious diseases that spread between humans.

It is only recently that attention has been drawn towards the insidious nature of zoonoses in the food system. In part this relates to investments in rigorous and organised programmes that use epidemiology and economics research to assist in decision-making. Similar to the disease and response processes of the major diseases in animal and humans, major foodborne diseases have created a need to invest and investigate further the impact of zoonoses in the food system. Of greatest note in recent times are:

- the emergence of new zoonotic diseases such as bovine spongiform encephalopathy (BSE) and highly pathogenic avian influenza H5N1; and
- the impact of foodborne pathogens such as *E.coli* O157, salmonella and campylobacter.

New problems relating to zoonotic pathogens mean that the major impacts of livestock diseases are related to human health and welfare (Shaw 2009). In developed countries these impacts can be enormous, dwarfing the production losses due to disease. Some of these diseases also create large impacts due to food scares and trade restrictions, and implications in other larger aspects of the rural economy.

45.2 Context

The increasing complexity of livestock production and their associated value chains had a background of changes in the political and institutional environment. From the late 1940s to the 1970s, state action was accepted to be important in economic and agricultural development. However, during the 1980s there was a change in thinking that stressed the market as a way to organise economic activity, supported by a small or even a minimal role for the state.

¹ It is recognised that some diseases were controlled well before this period (see Fisher 1980), however major breakthroughs were mainly made in the period suggested.

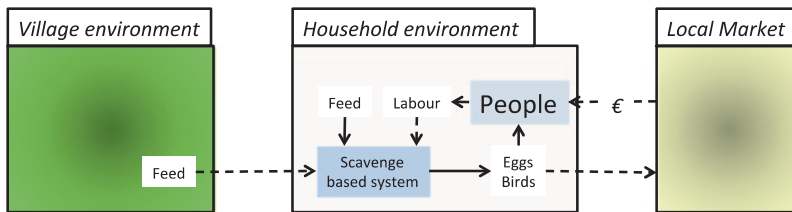


Fig. 45.1 Scavenge based poultry system

Different elements of these changes in public policy have had varying impacts on zoonoses management and public health in general. Until the 1980s animal health was seen as a public good and involved government services. However, pressure on public budgets and an increasing role for the private sector saw privatisation of many former governmental veterinary services and activities. The public health systems suffered less, but zoonoses control often fell between weakened veterinary systems and relatively powerful human health institutions and agencies with a focus on diseases and health problems that affect largely people.

In addition to the dynamics of the changes in the public funding of health systems, the food systems have evolved creating more difficulties in the management of pathogens.

45.2.1 *Changing Context of the Food Systems that Feed us*

Over a period of around 200 years the world has moved from relatively simple livestock value chains to increasingly complex ones. The pace of this change has accelerated in the livestock sector with the increasing use of intensive systems where animals are housed and fed and no longer allowed to scavenge or graze. In the case of poultry this has been particularly dramatic, scavenge based systems for poultry production were common and used mainly local resources, with the household consumption of products and the infrequent sale to local markets (see Fig. 45.1). The presence of these systems in a local environment allows people to observe the health of the animals, and it is also probable that they will see the slaughter of the animals. The information on production and processing allows people to make individual judgements of how best to prepare and eat their food.

In the complex food value chains, that are now dominant in many parts of the world, primary production has complex relationships with consumers through processing and marketing companies. The links in the chain are maintained by middle men, transport companies and finance groups. Where the value chains become integrated, i.e. owned and controlled by one company, the middlemen disappear. In addition, consumer demands have become more sophisticated for processed food and food with zero risk of foodborne diseases (Rushton 2009). For the intensive poultry systems that are increasingly dominant in the provision of meat across the world,

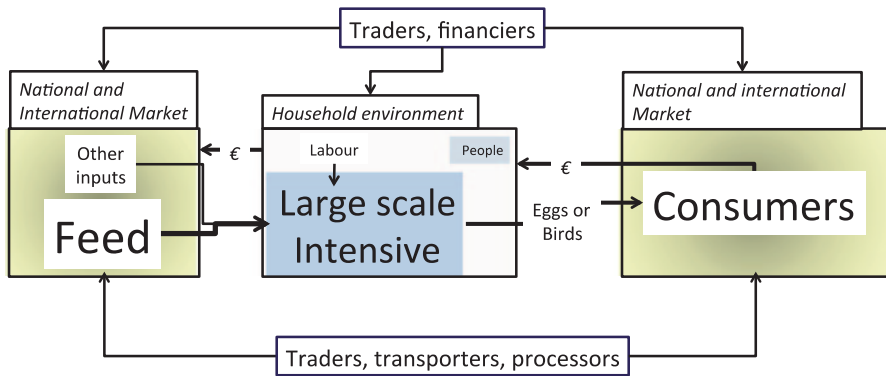


Fig. 45.2 A schematic diagram of the complex intensive poultry food systems. (Rushton 2009)

the system is global. Day-old birds and feed are produced in different parts of the world, the fattening of birds and their slaughter take place some distance from the families that eat the meat (see Fig. 45.2). These systems do not allow an individual to gain much insight in or information on the origin of the meat eaten, the consumer has to be given that information with labelling and/or systems of trust on the quality, which includes food safety, of the product.

The changes in the livestock food systems have not been gradual, there have been jumps associated with major technological changes. These have come at different points in the food system. For example the use of vaccines against Gumboro disease in poultry has allowed birds to be housed in large numbers and changed the way they have been fattened. The ability to freeze meat allows the slaughter and transport of carcasses from distant places to points of consumption. These changes have also been stimulated by the social and economic change in society, the growth in human populations and the greater proportion of people found in urban rather than rural areas. The urban based people require food to be produced and processed for them and the tendency across the world is for food systems to become more technologically and economic efficient in order to provide food that is relatively cheap in comparison to other goods in society. Overall this has led to fewer and fewer people to be involved in primary production; for livestock this means that animals are managed in larger herds or flocks and more animals per person handling them. The economic activity of the food system is found in the processing, catering and retailing areas where food preparation that would have traditionally been done in the home is now carried out by third parties. The shape of the food system in terms of numbers of people is therefore like a pyramid with a large number of consumers being supplied with animal source proteins produced by fewer and fewer farmers, who are selling to complex food processing, retailing and catering companies (see Fig. 45.3).

In the UK it is estimated that only 336,000 people (0.6% of the working population) are involved in primary agriculture, yet the food processing, retailing and

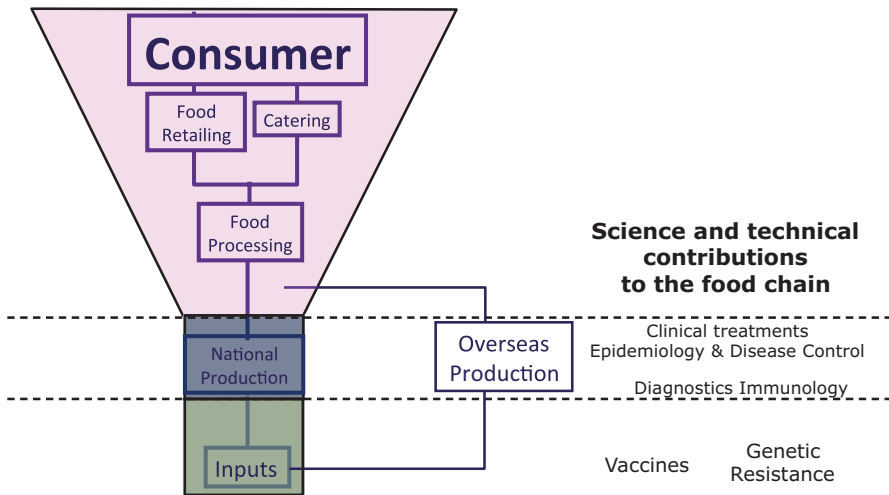


Fig. 45.3 A schematic diagram of the food systems. (Rushton et al. 2012)

catering part of the food system employs around 12% of the working population and generates 7–8% of the Gross Domestic Product (GDP). This food system relies on imports from other countries and feeds on a daily basis for more than 60 million people. In short, never have so many been fed by so few.

The scale of the current food systems and the additional complexity given by the increased number of people and links involved in the supply chain implies that the presence of infectious diseases in these system, including zoonoses, impact a wider number and variety of stakeholders, sectors and people in the chain, bringing also new challenges to disease control.

45.2.2 Classification of Zoonoses

Zoonoses are diseases and infections that are naturally transmitted between vertebrate animals and humans (WHO 2013). This group of diseases is generally classified according to the zoonotic agent itself, the degree of human-to-human transmissibility or through the route of transmission of the disease from animals to humans (Karesh et al. 2012; Lloyd-Smith et al. 2009). The classification according to the route of transmission groups zoonoses into diseases mainly transmitted through food or foodborne zoonoses, such as salmonellosis or campylobacteriosis (EFSA 2013); diseases mainly transmitted to humans through other means than food, i.e. by vectors, or through direct contact or close proximity with infected animals, such as avian influenza and Q fever (EFSA 2013), and zoonoses with multiple routes of transmission, including through food and direct contact, such as brucellosis.

While foodborne zoonoses are particularly important in terms of direct impact for the food industry, indirect costs of zoonoses transmitted by other means than

food can also produce significant impact through indirect costs to the food industry (Rassy and Smith 2012; McLeod et al. n. d.).

45.2.3 Measuring Impact

The impact of zoonotic diseases is challenging to assess. The greater complexity of measuring the impact of zoonoses relates to the frequent underreporting of these diseases and to the multiple sources of losses that are associated with zoonoses. In general they cause problems in different sectors such as the public health, the animal health and the environment, with no particular sector being affected strongly, but with an overall large impact (Grace et al. 2012; Keusch et al. 2009).

Direct and indirect costs in the animal sector, on the public health sector, on the environment and at their interfaces, and both on the public and on the private levels, contribute to the overall impact of zoonotic diseases. However, current estimates and tools available to measure these economic impacts tend to be specific to each sector. While some estimates have incorporated aspects of animal costs and human costs (Bennett and IJpelaar 2005; Choudhury et al. 2013), the different components of impact are usually considered individually rather than in an integrated way (Grace et al. 2012), meaning that the full extension of impact associated with zoonotic disease is seldom captured. While the distinction between direct and indirect costs might not be always straightforward, the following sections will reflect in more detail on the direct and indirect costs of zoonoses.

a. Direct costs of zoonoses

– Direct costs of zoonoses on the animal sector

Direct costs of zoonoses associated with livestock production relate to losses due to morbidity and mortality in food producing animals, which lead to a decrease in the expected output due to disease, treatment costs, and the increase in expenditures on non-veterinary resources (Bennett and IJpelaar 2005).

Morbidity and mortality of animals due to zoonotic diseases carry also other losses related to the wider social, cultural and economic value of animals and their health and welfare to people. Animals can be a source of income and employment, provide draught power and organic fertilizer, serve as means of transport, particularly in low income settings, serve as guardians of livestock and households and companions to people (Meslin 2006; Torgerson 2013), and also serve as a form of insurance and status.

Generally, morbidity and mortality effects in animals are measurable in monetary units. Frequently used tools include cost-analysis, incorporating the losses mentioned above (Bennett and IJpelaar 2005), and decision tree analysis, which might model different scenarios of production (Carabin et al. 2005; Choudhury et al. 2013). A key constraint identified in these analyses relates to the scarcity of disease-related data available to populate the economic models developed (Bennett and IJpelaar 2005). Other methods used include the elicitation of expert opinions to provide a rank of zoonoses with highest impact and to inform prioritization (Grace et al. 2012).

– Direct costs of zoonoses on the Public Health sector

Likewise, direct costs of zoonotic disease for the public health sector are also related to mortality and morbidity in the human population.

Currently, the most widely used methodology in the estimation of the impact of disease in the human population is through the use of disability-adjusted life years (DALYs), the method currently used to measure the global burden of disease estimates regularly produced by the World Health Organization (WHO 2004). DALYs provide a summary measure that allows to combine both mortality and morbidity effects and indicators, by presenting the present value of future years lost due to premature death or due to poor health (Grace et al. 2012). Its use allows the comparison of results across a multitude of illnesses and populations. However, DALYs only estimate the disutility to the individual of being ill, and do not capture medical costs of illness to the individual or society (Grace et al. 2012). Other summary measures available include the quality-adjusted life-years (QALY) that while calculated using a different methodology, also combine mortality and morbidity effects. QALYs have been more used on the evaluation of medical interventions as a health outcome for cost-utility analysis (Gold et al. 2012).

Recent estimates of the burden of zoonotic disease indicate that zoonoses contribute to 26% of the DALYs lost to infectious disease and 10% of the total DALYs lost in low income countries, respectively, and to 1% of DALYs lost to infectious disease and to 0.02% of the total disease burden in high income countries (Grace et al. 2012). Particularly in low income countries, this burden is amplified by losses associated with malnutrition, also closely linked to zoonotic disease (Grace et al. 2012).

For foodborne diseases, estimates of the impact on public health, produced by the UK Food Standards Agency, are available for the UK (Table 45.1).

– Costs of zoonoses on the environment

Zoonotic diseases impact on the ecosystems by threatening the diversity of species as well as the number of connections between them, affecting the stability of the ecosystems (Grace et al. 2012). Linked to the complexity associated with valuation of the ecosystems and its measurement, tools for the assessment of the costs of zoonotic disease to the ecosystems are less developed, but comprehensive assessment frameworks considering the various burdens of zoonotic disease in human, animal and ecosystem health of zoonotic diseases have been proposed under the Ecohealth approach (Grace et al. 2012).

b. Indirect costs of zoonoses

Indirect costs of disease are those derived from the human reaction to the presence of or to the risk of presence of a disease (Meslin et al. 2000). These include costs associated with disease prevention and establishment of control measures, market impacts, such as trade and travel regulations and restrictions, and those derived from consumer reaction and changes in consumer confidence in the food chain. They can further include costs accrued from unproductive downtime on farms and organizational costs related to disease response from the veterinary, food and public health services (Keusch et al. 2009).

Table 45.1 Foodborne pathogen problems in the UK in 2007. (Jones 2009)

Pathogens	Total Cost		Death		Hospitalisation		Cases	
	%	Rank	%	Rank	%	Rank	%	Rank
<i>Campylobacter</i> spp.	33	1	18	3	83	1	36	1
Salmonella non-typhoidal	15	2	21	2	6	2	3	5
VTEC O157	4	5	5	5	2	5	0	10
<i>Listeria monocytogenes</i>	12	3	37	1	2	3	0	11
Norovirus	6	4	7	4	1	8	19	2
Total	£ 1520 million		443		18,906		925,766	

– Prevention, control and surveillance

To avoid the losses due to disease mentioned above, another economic cost accrues from efforts to prevent, control or eradicate a disease. Examples illustrating this are provided by control and prevention measures carried out to tackle some zoonotic events, such as BSE (see Box 1), Highly Pathogenic Avian Influenza (HPAI, see Box 2) or bovine tuberculosis, where control and surveillance activities are estimated to cost £ 74 to 99 million per year in the UK (Torgerson and Torgerson 2008).

Box 1. Economic Impact of Zoonoses—The BSE Example

The impact of the BSE crisis has been the subject of numerous assessments in several of the countries affected (reviewed by Keusch et al. 2009; The World Bank 2010). The disease has led to important direct and indirect losses. Before the link between BSE in cattle to Creutzfeldt–Jakob disease (CJD) in humans was established, the disease losses were mainly linked to the loss in value of infected carcasses and to the costs of establishing control measures, namely the disposal of specified risk material (Atkinson 2007). The establishment of the link between the two diseases meant the additional emergence of important indirect costs linked to market impacts, including the contraction in domestic demand of beef products, loss of export markets and a fall of beef cattle prices (Atkinson 2007). Beef consumption and domestic prices of cattle, beef and beef products were reported to have substantial drop-offs in many countries (Probst et al. 2013; Serra 2011).

To respond to the crisis, a series of preventive and control measures have been implemented in the countries affected. In the UK, the estimation of the costs associated with control and regulation compliance in the years of 1996/1997 indicated additional costs of around £ 25–50 million, to which added costs associated with slaughtering and culling of £ 220 million (Atkinson 2007). In Germany, the total costs associated with prevention, control and surveillance of BSE were estimated to range between € 1.8 and 2.0 billion, with approximately 54% of the costs being incurred by the extension of the feed ban for animal protein to all farmed livestock and 21% to active surveillance

(Probst et al. 2013). An analysis of the cost-effectiveness of these measures in the Netherlands indicated a cost of € 4.3–17.7 million, from 2002 to 2005, per life year saved (Benedictus et al. 2009).

Exports were also strongly impacted by trade restrictions put in place. For the UK, the export market of beef and trade in live calves, worth £ 670 million in 1995, was lost with the trade ban imposed in 1996 (Atkinson 2007). These losses associated to a loss in output from beef and related products, were offset, in some instances, by general equilibrium outcomes (Wigle et al. 2007). In Europe, for example, poultry, pork, vegetables and milk products benefited from the BSE crisis (Benedictus et al. 2009). In May 2003 the Canadian government reported the detection of a single case of BSE in a national cattle population of nearly 13.5 million animals (FAO 2006). This led to 40 countries banning the import of a large range of live animals and livestock products from Canada. Mitura and De Piéto (2004) estimated that the impact of the international livestock trade ban was significant for Canada. In 2003, Canadian farm cash receipts from cattle and calves were estimated at \$ 5.2 billion, a sharp drop of \$ 2.5 billion (33 %) from 2002. At farm-level it was estimated that on average a family farm with an unincorporated beef unit would have lost \$ 20,000. The more wide-ranging impact of the trade ban was the movement of cattle from Mexico to the USA to fill the demand for store cattle that would have come from Canada. While this has created a positive impact for cattle producers in Mexico, it has meant that beef prices in Mexico have risen affecting Mexican consumers, and that the USA is potentially importing animals from areas with low tuberculosis status (Ayala and Velasco 2005). Later in 2003 the USA also declared the discovery of a single animal with BSE (out of an estimated cattle population of 96 million, FAO 2006) which led to 53 countries banning the imports of American beef. Coffey et al. (2005) estimated that the losses associated with this trade ban were between \$ 3.2 and 4.7 billion. These authors also estimated that BSE has had considerable costs in terms of increased needs for surveillance at a farm and slaughterhouse level. On an international level the use of BSE cases in Canada and USA as a trade barrier can have a negative impact on disease reporting. Livestock exporting countries, whose economies have far less ability to absorb rapid changes in export demand for livestock products, are unlikely to report minor levels of animal disease where there is a risk of exaggerated and rapid trade bans.

Estimations of losses on the public health sector are not as readily available in the literature as for the animal health sector and food chain. An estimate from the UK points to running costs associated to staff time and expert committees of 2.5 million GBP, in 1988–1996. The cost of patient care for CJD patients were considered too uncertain to be quantified (The BSE Inquiry Report 2000).

– **Market impacts: from trade and travel regulations to consumer reaction and product recalls**

The indirect impact of zoonoses, associated with losses due to changes in consumption patterns and/or trade and travel restrictions imposed as a consequence of zoonotic disease outbreaks, can be extensive and last beyond the duration of an outbreak, depending on the risk perception of trade partners and tourists.

The example of the Severe acute respiratory syndrome (SARS) epidemic demonstrated the economic impacts of travel restrictions affecting tourism and its contribution to reductions in GDP growth in some countries, through reductions on service exports, particularly tourism related exports (Xiaoqin Fan 2003; Keusch et al. 2009). For China, Taiwan, Hong Kong and Singapore, this impact has been estimated to be \$ 13 million, or 0.5–1.1% of the GDP (Keusch et al. 2009). The 1994 plague outbreak in India also led to economic losses due to internal and external travel restrictions (Keusch et al. 2009). More recently, the H1N1 emergence in Mexico resulted in a reduction of almost a million overseas visitors and losses of around \$ 2.8 billion for the country's economy (Rassy and Smith 2012).

Losses due to changes in consumption patterns and trade disruption can also be highly visible. In the European Union, and following the BSE food scare, more than half of the consumers were fearful of BSE and unsure as to whether beef meat was safe for consumption (Bánáti 2011). This led to important losses explained in further detail in Box 1. While BSE has led to a significant drop in consumption and a market shock, other scares have been relatively short-lived with consumption returning back to previous levels, not causing an overall loss, but a disruption in the food system which may make some businesses go bankrupt, leading to loss of employment and /or restructuring of the industry.

Product recalls have become an important component of the food system as the value chains have lengthened. Of the recent major food recall incidents, many have been related to zoonotic pathogens and contaminants, such as *E.coli* in beef in the USA in 1997 (with a cost estimate of \$ 25 million on recalls plus significant loss in company value), salmonella on vegetables and vegetable products such as peanut butter (cost of incidents ranging between \$ 70 and 250 million) and in Europe some incidences around the detection of dioxins in meat (for Ireland, the cost estimate of the recall of pork meat was € 200 million in 2008).

Box 2. Economic Impact of Zoonoses—Highly Pathogenic Avian Influenza in Chile

In 2002, Chile reported for the first time an outbreak of HPAI. This was also the first isolation of avian influenza virus in South America (Lupiani and Reddy 2009). The poultry industry in the country produced, at that time, 400,000 tons per year of fresh poultry meat, with exports, mainly to Mexico and the European Union, following an increasing trend (\$ 69 million in 2001, \$ 44 million in 2002 and \$ 72 million in 2003) (Orozco 2005). Following the outbreak, the access to export markets was closed (Orozco 2005).

As a response, the national authorities put in place a series of mitigation measures, including stamping out of affected farms, setting up of surveillance, pre-diagnosis quarantine, depopulation, movement control, and increased biosecurity (Max et al. 2007) and to regain access to the export markets as soon as possible, a zoning strategy was adopted (Orozco 2005; Max et al. 2007). The culling of the two infected farms to stamp out the disease resulted in the destruction of 560,000 breeding chicken and turkeys (Rojas 2009). Within 7 months, Chile was declared free from HPAI (Max et al. 2007). The initial financial impact of the disease was calculated by Verdugo et al. (2006, cited Rojas 2009) to be \$ 31.7 million, with costs largely borne by the private sector. An economic impact assessment of HPAI in Chile estimated that over the whole economy losses reached \$ 250 million (Wright 2004)

In Europe, the costs of recall are strongly related to the traceability systems in place. If traceability is poor, then large amounts of product have to be recalled that are likely to be unaffected by the problem.

45.2.4 Balancing Direct Costs of Disease and Reaction

In summary, zoonotic disease in food systems creates two sources of economic cost. First, there are the value losses caused by the negative effects of disease itself when people are ill or die leading to reduced productivity, lost income, and people suffering, including family members or friends who take on the role as unpaid caregivers. Similar losses occur in animal populations when animals are ill or die leading to production losses and negative impacts on animal welfare. The second economic cost is caused by people's reaction to disease to limit the negative effects of hazards. The additional resource costs incurred in the attempt to offset the output value losses have a positive opportunity cost, as they might have been used to generate other outputs which are valued elsewhere in the economy.

In assessing the rationality of any resource-using decision, the key criterion is whether the value of outputs consequently recovered is at least sufficient to cover the additional resource costs. As a basic rule, to achieve the maximum net benefit, the total impact of disease should be as small as possible. In other words, a balance should be found between the level of disease and the associated losses as well as the expenditures made to tackle the disease in animal and human populations. Frequently, the economic cost of disease is presented as an aggregate figure that comprises both the impact caused by the disease and the impact caused by the reaction to the disease (Rushton 2013). To find the right balance between losses and expenditures, it is important to understand the relationship between the two.

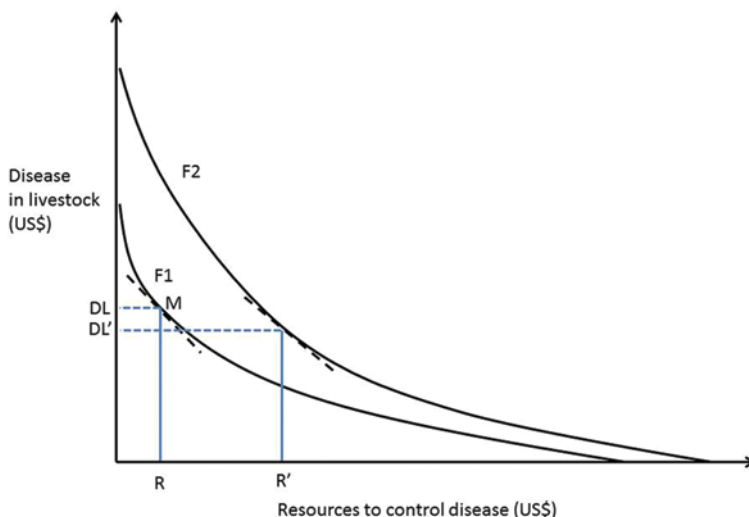


Fig. 45.4 The relationship between output losses and control expenditures with externalities. (Anon 2012) (Note: F1 is the situation where externalities are not taken into account whilst F2 takes externalities into account)

At societal level, the cost of resources committed to mitigation should at least be compensated by the value of the resulting recovered outputs for a policy to be acceptable; and, ideally, the net benefits to society should be maximised (McInerney et al. 1992). Because the “external costs” of zoonotic disease are commonly not taken into account in markets, outcomes result that are not socially optimal, i.e. social welfare is lower than it might otherwise be.

Consequently, the loss-expenditure curve can be expanded to take into account the negative externality resulting from zoonotic disease, as illustrated in a recent OECD report (Anon 2012). In Fig. 45.4 the economically optimal balance of expenditure and disease losses is shown at point “M”, where the level of resource expenditure is R and disease loss is DL . When the value of disease losses is higher because of the externalities due to zoonotic disease, the loss-expenditure curve might be as shown by curve $F2$. In such a case, the optimum level of resource expenditure should be at a higher level (R'), and disease losses at a lower level (DL'). In this example, the curve cuts the x-axis which means that the disease could be eradicated (although it would not be the least-cost economic optimum).

Identification of the economic optimum for zoonotic disease mitigation depends on the price ratio between mitigation resources and mitigation outcome (= loss avoidance). The optimal level can be influenced by two key factors, namely technical changes that lead to an improvement of disease control measures with no price changes and changes in the value of losses avoided relative to the costs of mitigation (Howe et al. 2013). Consequently, when the value of unpriced negative externalities are taken into account, the total losses increase, which impacts on the optimal point of mitigation as illustrated in Fig. 45.4. To be able to add the negative externalities,

their value must be added to the total losses. Often their value cannot be directly deducted from prices in the conventional sense; instead they must be valued using indirect estimation methods, such as the DALY approach described above. Similarly, the value people place on the welfare of their companion and recreational animals can be estimated for example from how much they spend on veterinary services and medicines. Freedom from fear of infection is more problematical to quantify, but may be revealed by changes in people's normal consumption behaviour.

Disease mitigation programmes at national level generally comprise two important components, namely surveillance and intervention. Surveillance is defined as the "systematic, continuous or repeated, measurement, collection, collation, analysis, interpretation and timely dissemination of animal health and welfare related data from defined populations, essential for describing health hazard occurrence and to contribute to the planning, implementation, and evaluation of risk mitigation measures" (based on Hoinville et al. 2013). In other words, surveillance provides information for interventions directed at loss avoidance. Surveillance and intervention are often inextricably linked; they can be technical substitutes or complements (Howe et al. 2013). The above conceptual basis to define the optimal level for mitigation can then be extended to identify the optimal combination of surveillance and intervention, namely the point where the marginal cost of surveillance and intervention (combined at least cost) equal the marginal benefit (= loss avoidance) on the expansion path (Howe et al. 2013). The expansion path (Fig. 45.5) links all identical tangent points on iso-mitigation curves (along such a curve, the losses avoided are the same for all combinations of surveillance and intervention) with the gradient corresponding to the price ratio for surveillance and intervention. Each point of tangency is a least-cost combination for surveillance and intervention for the given price ratio. If the iso-cost line represents a budget constraint, the surveillance and intervention resources cannot be increased above this level. In Fig. 45.5, the optimal location on budget line BB' would be at H for A3 avoided losses, although H' would also be a feasible, albeit inferior use of resources. If adding externalities such as negative effects of disease in people, the point H would no longer be optimal and a case would need to be made to increase investment to be able to reach point K (Häsler 2011; Howe et al. 2013) (45.5).

In the examples used so far, it was assumed that there would be diminishing marginal benefits (= loss avoidance) with increasing expenditures for disease mitigation. In theory, it may well be the case that there are disease mitigation programmes, where this is different. For example, it may be that no loss avoidance is achieved at low levels of expenditure (marginal benefit = zero), but that expenditures need to reach a certain threshold for an effect to become noticeable, or that there are increasing marginal benefits at first followed by diminishing marginal benefits (Tisdell 1995). Such scenarios obviously would lead to different optimal points of disease mitigation, as illustrated by Tisdell (1995).

Importantly, only by understanding these relationships it is possible to make the best use of the resources available for disease mitigation and reduce the economic cost of zoonotic disease to a minimum. Empirical data allow demonstrating whether a disease mitigation programme is subject to increasing or diminishing returns. Only

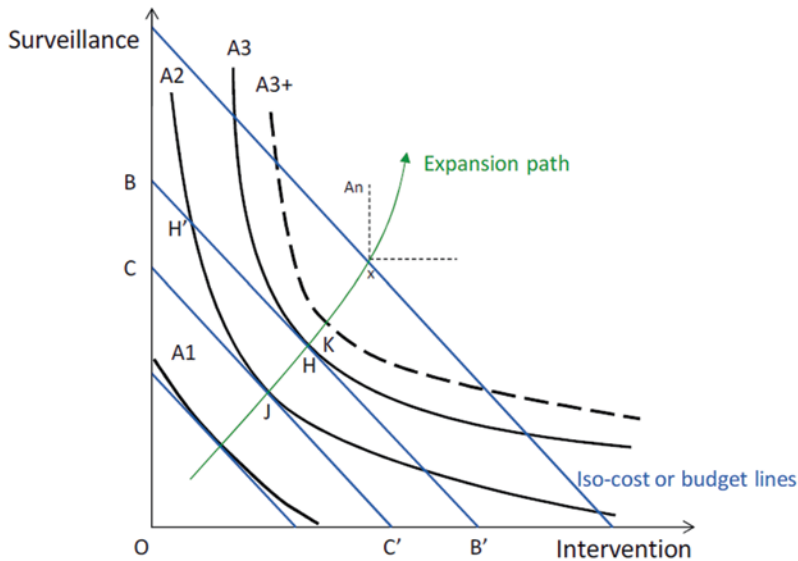


Fig. 45.5 An iso-mitigation map with an expansion path to identify the optimal balance between loss avoidance, surveillance and intervention resources. A1, A2, A3, A3+ and An are distinct levels of losses avoided. J, H, K and x mark least-cost combinations of surveillance and intervention corresponding to distinct levels of loss avoidance. (Häsler 2011)

with information about the relationships described, economic analysis of zoonotic disease mitigation can move towards an optimal level of investments; otherwise the analysis is limited to the assessment of acceptability criteria.

45.3 Economic Tools to Assess the Impact of Zoonoses and Interventions

When there is a choice to be made about the allocation of resources to zoonotic disease mitigation, it should be ensured that “the value of what is gained from an activity outweighs the value of what is being sacrificed” (Williams 1983). In other words, for an investment to be justifiable the benefits should outweigh the costs; an acceptability criterion commonly found in cost-benefit analyses that compare the costs and benefits of potential programmes in monetary terms.

In a nutshell, cost-benefit analyses compare the total discounted benefits of a project in monetary units with its total discounted costs in monetary units and recommend the implementation of the project if the benefits exceed the costs. It includes the definition of the useful life of the project, the estimate in physical units of benefits (losses avoided) and costs (mitigation resources used), translation of the physical units into economic values, the conversion of future values into present values by discounting, and finally the calculation of the net benefit (net present

value = total discounted costs—total discounted benefits). Because the benefit-cost ratios as choice criteria can be misleading when multiple options are compared, some authors recommended to use the net present value instead of the benefit-cost ratio (McInerney 1991; Tisdell 1995; Howe et al. 2013). In any assessment of this nature it is therefore important to review all measures of project worth, namely the net present value, the benefit-cost ratio, and internal rate of return and timing permitting an examination of the estimation of the benefit and cost streams.

A similar basic principle is seen in cost-effectiveness analysis, which is commonly used to assess human health interventions. To date, it has rarely been applied to animal health decision-making problems (Babo Martins and Rushton 2014). Cost-effectiveness analysis aims to assess the effect of a programme in non-monetary units in relation to its cost. In human health economics the effect often refers to the avoidance of illness or death, but the outcome of any objective can—in theory—be measured in various technical terms, for example reduction of CO₂ emissions or detection of cases of disease. However, it is important that the value of the effect in question reflects a (non-monetary or monetary) benefit. A special case to cost-effectiveness analysis is the least-cost analysis where two or more programmes or projects achieve the same effect. The economic assessment then aims to identify the cheaper option.

Importantly, all these fundamental concepts explained above only provide an estimation of the economic efficiency (optimal balance, acceptable combination, least-cost option) of technical feasible ways of dealing with zoonotic disease. Some authors have proposed frameworks that take into account wider issues, including risk management options and the understanding of the factors impacting those options (Narro et al. 2012; Grace et al. 2012). It is the case of the framework proposed by Narro et al., consisting of a modified risk analysis framework to enhance reduction of zoonotic disease burden, including the analysis outputs of animal and human disease transmission models and economic impact models (Narro et al. 2012).

Independent of which type of economic efficiency criterion is to be assessed, there is a need to attribute value to the different impacts mentioned above. Value can be defined as the importance, worth, or usefulness people attach to something, reflecting their judgment of what is important in life, and which in economic activity determines the choices made about the use of scarce resources (pers. comm. Keith Howe). A short summary is provided here:

- When dealing with morbidity and mortality in animals due to zoonotic disease, units of physical losses (e.g. number of animals that died, number of animals suffering from milk loss, rate of milk loss) can be combined with data on production (e.g. milk yield) and/or market prices (e.g. market value of the animal, milk price). Illustrations of how such losses can be calculated can for example be found in Mcdermott et al. (2013) and Herrera et al. (2008). An overview of various techniques suitable to assess the economics of animal disease can be found in Rushton et al. (1999).
- The negative impact of disease on human health is commonly measured using DALYs or QALYs, (see details above). Further, the cost-of-illness (COI) methodology attempts to measure all the costs associated with a particular disease or

condition. It takes into account the direct costs of illness (e.g. visit to a physician, laboratory or treatment expenses), indirect costs (e.g. value of lost productivity from time off work due to illness), and intangible costs (e.g. psychological costs due to pain or suffering).

- Impacts on the ecosystem can either lead to production losses (e.g. when pollinators such as bees are affected by disease in turn causing harvest losses) or the reduction of ecosystem services to people. For example, if an area cannot be accessed anymore, because of a risk of zoonotic disease transmission, a value loss occurs to people in that they cannot use the area as they usually would. There are several techniques available in environmental economics to attribute a value to the personal use of ecosystem services. Techniques based on revealed willingness-to-pay (WTP) for an ecosystem service focus on prices people are willing to pay to make use of the environmental good; they include hedonic pricing, market price method, productivity method, and travel cost method (King and Mazzotta 2013). The travel cost method is used to explain the underlying principle of the revealed WTP approach: it is a popular method to estimate economic use values associated with ecosystems people use for their recreation, such as recreational fishing or hiking. The method can be used to assess changes in access costs for or quality of a site or elimination or addition of a site. The fundamental principle of this method is that the travel costs people need to cover to visit the site reflect its price and the number of trips in relation to the price allows estimating a demand curve as it is done for goods that have a market price. An example of an application of this method can be seen in the paper by Shrestha et al. (2002) who measured the value of recreational fishing in the Pantanal in Brazil. When dealing with ecosystem services that are not reflected in market prices, people cannot reveal what they are willing to pay for those services. In such cases, methods are used that ask people directly what they are willing to pay for having a service or what they are willing to accept in terms of compensation for losing a service.
- The willingness-to-pay or contingent valuation approach is also used in animal health to attribute a value to food safety or animal welfare. The approach is based on the assumption that the maximum amount an individual is willing to pay for a commodity reflects the value it has for this person. Miller and Unnevehr (2001) for example conducted a household survey to investigate consumers' WTP for enhanced pork meat safety. They found that roughly 80% of the consumers were willing to pay at least \$ 0.10 more per pound of certified safer pork. Another study used a hypothetical market scenario in the UK to investigate people's WTP to support legislation to phase out the use of battery cages in egg production in the EU by 2005 (Bennett 1998). The survey showed a mean WTP of £ 0.43 increase in price per dozen eggs (with a market price of around £ 1.40 per dozen), purporting to indicate the value respondents attributed to improved animal welfare. The main criticism of the WTP is that it does not give reliable valuations, since the choices are often hypothetical and people tend to overestimate their willingness to pay. Another drawback is that non-users of a good or service might find it difficult to attribute a value to it because their knowledge of it is very limited.

- Various outbreaks of zoonotic disease in the past showed that food safety scares can alarm consumers to the extent that they reject consuming certain products. Such a reduction in demand caused by loss in consumer confidence can lead to a reduction in market prices and is reflected in a drop in quantity demanded and the associated changes in market prices. Similarly, zoonotic disease outbreaks can lead to movement or export bans, which impacts on the quantity of product placed on the market and consequently affects prices. The value of these changes in supply and demand can be assessed using surplus models to measure producer, processor and consumers surplus changes, as illustrated for avian influenza outbreaks in South East Asia and the United States, respectively (Hall et al. 2006; Paarlberg et al. 2007) and BSE (Weerahewa et al. 2007).
- In countries where there are no substitution possibilities for foods potentially contaminated with pathogens, consumers may put themselves at risk for foodborne disease when consuming the food due to the lack of alternatives or they may increase the risk of malnutrition by excluding nutritious foods from their diets. Foodborne disease leading to diarrhoea reduces appetite and/or the absorption of nutrients in the body. Malnutrition on the other hand impairs the immune response and predisposes affected people to infection thereby creating a vicious cycle of malnutrition and infectious disease. Zoonotic disease can impact on nutrition in three ways: (1) through the avoidance of food because of food scares (as described above); (2) market shocks that impact on the availability of livestock and fish products (due to reduced production and/or control measures such as movement or export bans), or (3) the direct impact of infectious pathogens on health. There is a wide range of different methods available to assess food and nutrition security indicators; a review has recently been published by Pangari-bowo et al. (2013).

These valuation approaches can be used to measure the impact of zoonotic disease, and/or form part of an economic assessment to inform resource allocation for zoonotic disease mitigation.

45.4 Conclusions

Economics provides several tools and frameworks that can be used in the measurement of the impacts and to inform resource allocation for zoonotic disease mitigation. However, the measurement of the impact of zoonotic diseases presents several challenges. The impacts of zoonoses are felt in multiple sectors, in multiple links of increasingly complex value chains, and in the interface between sectors and jurisdictions. These multiple dimensions are generally complex to capture as whole, with many studies focusing on impact assessments per sector and failing to capture the entire realm of effects. In addition to the need of addressing impacts in a wider context, aspects such as unused human, financial and capital capacity in the food system, reduced confidence in the market place, particularly for export markets and important lags created in terms of confidence and investment—often taking years to

recover capacities, skills, markets—should be incorporated in future, more refined, impact assessments of zoonoses. Data availability and quality to populate assessments represents a further challenge. Underreporting of cases of zoonotic disease, particularly in low-income settings, are for example believed to be contributing to the underestimation of the burden of these diseases in the human and animal populations (Keusch et al. 2009; DFID 2011), therefore influencing disease mitigation decisions and contributing to the perpetuation of their impact.

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