The Economics of Animal Health and Production

This book is dedicated to my boys Adam and Ben and my wife Rommy Evelyn,
who have sacrificed much during the book's preparation, and without their love and support
it would never have been possible.

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By

Jonathan Rushton

With Guest Contributors

Foreword by

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Hernán Rojas is a veterinary epidemiologist who has made significant contributions on animal health policy. He has a veterinary degree from the University of Chile, Santiago, and a Master's and PhD in veterinary epidemiology from the University of Reading, UK. Between 2001 and 2006, he was the Chief Veterinary Officer of Chile. Currently he is the Director of Chile's National Institute for Agriculture and Livestock Development (INDAP), which is part of the Ministry of Agriculture.

Alexandra Shaw is an economist, whose specialization is animal health. She began her working career in Nigeria, and later wrote her PhD on the economics of controlling tsetse and trypanosomiasis in West Africa. Most of her career has been focused on Africa, where she has worked in over twenty countries. She has also done some work in South America, for WHO on various zoonoses and worked on the economic aspects of animal health control programmes in the EU. She has taught veterinary economics in British, German, French and African universities. Currently, she divides her time between teaching and consultancy work. Her main research interests are trypanosomiasis and the economics of other zoonotic diseases.

Alistair Stott is head of the animal health economics team within the Research and Development Division of SAC. He graduated with a degree in agriculture in 1980, followed by a PhD in animal physiology and genetics. Alistair combines this strong scientific and agricultural background with nearly 15 years working in farm business management and animal health and welfare economics. His background is ideal for encouraging scientists and economists to work together to tackle problems facing agriculture. As well as animal health and welfare, he has worked on the development of selection indices for animal breeding.

Clem Tisdell has a broad range of research interests which include topics in agricultural and ecological economics, such as those involving livestock management, genetic diversity and animal health issues. He has been involved in consultancies or research projects for bodies such as ACIAR, FAO and ILRI. His applied research has focused mainly on Asia and the Pacific. He is currently Professor Emeritus in Economics at the University of Queensland (Australia) and is jointly investigating the adjustment of Vietnamese pig producers to changing market conditions.

Martin Upton has had a long career as an agricultural economist, first at the University of Ibadan, Nigeria, and subsequently at the University of Reading. Over the last 20 years he has specialized in the economics of livestock production, marketing and development policy, mostly in Africa and more recently in the UK. This has involved studies for ILCA and ILRAD (now ILRI), FAO, DfID and The Netherlands Government. For DEFRA, he led the Reading team conducting cost–benefit analysis of the 20-day standstill and continued as peer reviewer for further studies on FMD control. He is currently participating in a broad review of animal health and welfare policies for DEFRA.

Rommy Viscarra is a veterinary epidemiologist who specializes in animal health control and extension. She has experience in animal health issues in Bolivia and in the Americas through working with FAO, WHO, DANIDA and USAID. Her key interests are animal health education in schools to promote community development and sustainable livestock production. She is an independent consultant.

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Preface

During the last 200 years, there has been massive socio-economic change through industrial and agricultural revolutions. This change has been associated with rapid increases in human and domestic livestock populations, and a movement of people from rural to urban areas. More than half the people in the world now live in urban environments where they have better access to work, but limited or no access to land and livestock to produce food. This implies that a majority of people are dependent on others for raw, semi-processed and processed food products. The efficient functioning of the livestock sector, encompassing all facets of input supply, production, processing and marketing, has become a critical issue for guaranteeing:

- that sufficient livestock products are available at affordable prices – food security; and
- that the livestock products are safe to eat – food safety.

Within the livestock sector, the livestock producers and business people involved in input supply and output processing and marketing need to be able to plan, make a profit and have a sustainable livelihood. The State also plays a critical role in facilitating how the livestock sector functions and develops in order to satisfy society's needs. Therefore, both the private and public sectors require economic theory and tools to understand the drivers of change for the livestock sector, and how to assess the impact of future actions and investments.

Background

The mid to late 18th century saw important advances in livestock production, in particular the recognition of more productive breeds. However, it was not until the middle of the following century that livestock production systems began to change. In Britain, the prices for meat began to rise in the 1840s, which stimulated an adoption of more intensive livestock production and a modification of housing systems. Around the same time livestock diseases became more problematic as livestock and livestock product movement increased and livestock value chains became longer and more complex. Of greatest note was the importance of economic diseases such as rinderpest, contagious bovine pleuropneumonia and foot-and-mouth disease (FMD). These diseases caused such problems that the State reacted and began to invest in veterinary services, education and research (Fisher, 1998). However, the response to diseases that

cause less dramatic losses to production, yet have serious impacts on human health, was not addressed in many developed countries until much later (Fisher, 1998; Waddington, 2002; see also Alexandra P.M. Shaw, Chapter 14). At international level, concerns on the need to control rinderpest stimulated the creation of the international office of animal health in the 1920s.

These initial investments in animal health and production, mainly associated with developed countries, were stimulated by large changes in livestock production and their associated value chains, perhaps best described as the first livestock revolution. The changes in the livestock sector created new disease problems, and also amplified the impact of contagious diseases. The response over time has been a combined public and private effort to control animal diseases in order to minimize their socio-economic impact. In some cases this has led to the eradication of disease in a number of countries.

Through a process of investigation of livestock production systems (Steinfeld and Mäki-Hokkonen, 1995; Sere and Steinfeld, 1996), and followed by an analysis of the supply and demand of livestock products (Delgado *et al*., 1999), it was realized that a new livestock revolution had begun. Unlike the previous revolutions, this was based largely on monogastric production and, to some extent, on changes in milk production. Similar to the early changes in livestock production and supply chains, it was being driven on the demand side by rapid human population increases, growing urban populations and increasing incomes. On the supply side, production and processing technologies had improved; there was availability of cheap feed grains and a reduction in bulk transport costs. The production changes of this new livestock revolution have been concentrated in the developing countries. Some raised concerns that the changes may leave some poor people behind (Haan *et al*., 2001; Heffernan, 2002; FAO, 2005; Owen *et al*., 2005) and others focused on the environmental impacts of change (de Haan *et al*., 1997; Steinfeld *et al*., 2006). What was not anticipated were the growing problems with the control of transboundary animal diseases and, more specifically, the resurgence of zoonotic diseases (Greger, 2007).

Therefore, over a period of around 200 years, the world has moved from relatively simple livestock value chains to increasingly complex ones. In the simple livestock chains a high proportion of produce was either consumed in the farm household or sold in local and regional markets. In addition, much of this food was processed within the household (see Fig. 1).

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 middlemen, 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 food-borne diseases (see Fig. 2). These livestock value chains can also be global.

The adoption of more complex livestock value chains has not been gradual; rather it appears to have been in jumps. The first of these probably occurred in the mid 19th century in Europe and North America with linkages to Australia, New Zealand and probably Argentina, and the

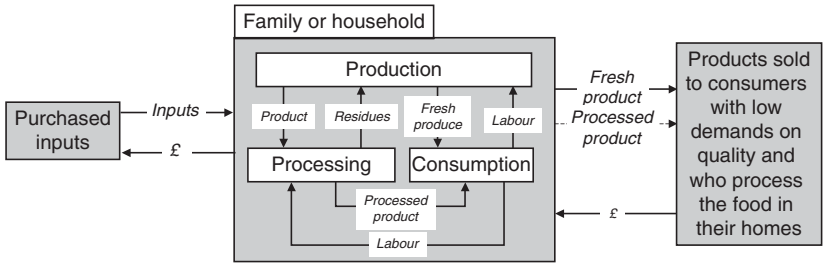

Fig. 1. Simple livestock value chains. (From Rushton and Viscarra, 2006.)

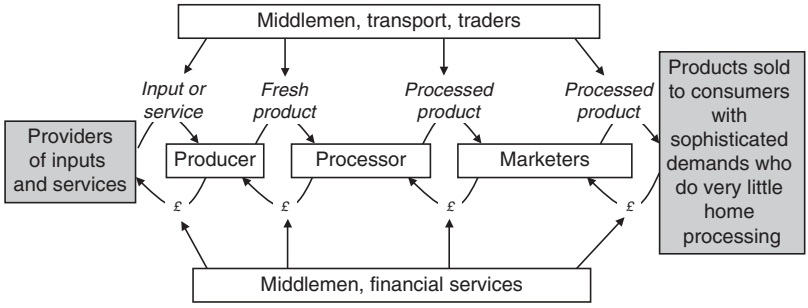

Fig. 2. A schematic diagram of the dominant complex livestock value chains. (From Rushton and Viscarra, 2006.)

second in the late 20th century mainly in Asia, but also in other developing countries. Both these jumps appear to be associated with societies in rapid transition from being largely rural to being urban and industrial. There is also an influence of the globalization of livestock and livestock product movement, associated with technological changes in transport and storage.

There has been a more gradual change in support of the new livestock value chains by animal health systems. The initial successes were with 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 and endemic diseases.[1] This was achieved through significant investments in human skills, building on previous investments in veterinary organizations, education and infrastructure from the mid 19th century onwards. The more recent investments, however, saw an intensified implementation of much more rigorous and organized programmes that used epidemiology and economics research to assist in decision making. Towards the end of the 1980s, many of these developed countries had become recognized as free from the major transboundary diseases and were beginning to make assessments of how to protect themselves from potential re-entries or re-emergence of disease. On a worldwide level, there were also successes that included the control and near eradication of rinderpest and the improved control of other transboundary diseases in developing countries with strong livestock export potential (Rushton, 2006). This would seem to indicate that methods of controlling disease, the production systems in which they are found and the methods used to assess their use are adequate.

However, there have been some major setbacks and large areas of the world have not been included in these advances (Rushton and Upton, 2006). The setbacks include:

- occasional introduction of transboundary diseases in developed countries such as FMD;
- emergence of new diseases such as bovine spongiform encephalopathy (BSE) and highly pathogenic avian influenza H5N1; and
- impact of food-borne pathogens such as *E. coli* O157 and *Salmonella*.

New problems relating to food-borne pathogens mean that the major impacts of livestock diseases are related to human health and welfare (see Alexandra P.M. Shaw, Chapter 14). In developed countries these impacts can be enormous, dwarfing the production losses due to disease. With other diseases there are large impacts due to food scares and trade restrictions, and implications in other larger aspects of the rural economy. This has raised questions

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

about how to prevent the entry of exotic, contagious diseases and the most appropriate way to control such diseases if they occur. In particular, environmental and welfare concerns were raised about the large-scale slaughter and disposal of affected animals, and there were worries about the economic losses outside the livestock sector that were caused by animal disease control (Thompson *et al*., 2002). In developed countries, there is also concern about endemic diseases, which are important in terms of production losses and control costs at farm level (Bennett, 2003), but remain largely uncontrolled. In developing countries investments in animal health are struggling to keep pace with the change in livestock sectors (Rushton *et al*., 2006a), although countries with a strong interest in trade would appear to be responding more strongly (Rushton, 2006).

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 organize economic activity, supported by a small or even a minimal role for the State.

In this context, safeguarding animal health was until the 1980s regarded as an inherently public and therefore predominantly governmental service. At this point the provision of animal health services became more open to the use of market institutions, and there were evaluations of government services against those of the private sector. Market failures in animal health services remained, for which there is a role for the State in the correction of such failures through the provision of goods and services, the setting and enforcement of regulations and through taxes and subsidies. In addition, other policies such as education and infrastructure can have important impacts on livestock disease prevention, control and eradication. However, understanding which interventions require public support goes well beyond the traditional analysis of farm-level technical animal health interventions. Such analysis requires both the old and new methods and skills (see Hernán Rojas, Chapter 23, on the changes in cost–benefit analysis in Chile).

The major questions for the economics of animal health and production

Rushton *et al*. (2007) developed a list of the major questions that need to be addressed by the economics of animal health and production based on the recent experiences with transboundary, food-borne and endemic diseases. They identified the following:

- How can one guarantee not just reasonably priced livestock products (*food security*) but also food that has low or almost no risk in terms of spreading disease (*food safety*) and from farming and processing systems that guarantee that animals are treated humanely (*animal welfare*)?
  - Food safety and other quality attributes have become an overriding concern for many developed countries in recent times and in part this reflects not just the power of media, but also the fact that food-borne diseases cause losses that make production losses at farm level appear insignificant (Perry *et al*., 2001, 2005; Rushton, 2002).
  - Animal welfare and ecologically 'sound' production practices are increasingly important and economically have become a selling point in many livestock product chains (Pritchard, 2004).
  - There is an increasing tendency to introduce food safety and welfare attributes into international law through the World Organization for Animal Health (OIE) and the World Trade Organization (WTO; Byron Nelson, 2005).
- What is the optimal level of resource allocation to the detection and prevention of exotic and emerging diseases?

  - It is important to recognize that even if an optimum level is identified through data collection and modelling (see Alistair Stott, Chapter 9), it will change over time with changes in the livestock sector. In order to address this constant evolution a data collection, analysis and monitoring structure is critical to ensure that policy makers have up-to-date information at hand (see Andrew James, Chapter 8).
  - With regard to the allocation of resources, there is a need to think about how to balance the allocation of resources between insurance that involves 'active' measures such as surveillance and vaccination versus more 'passive' measures such as the purchase of insurance policies and the establishment of contingency funds in the prevention, control and eradication of animal diseases (Rushton *et al*., 2006b).
  - Where livestock value chains are increasingly concentrated into large industrial integrated systems, who should insure against a contagious disease outbreak? Large industrial units have a much larger potential to contaminate and spread infectious agents in the surrounding environment than smaller units and the spillover costs are often borne by the State (Otte *et al*., 2007). Striking a balance where some of the spillover costs are recognized by the private sector could have important and positive implications for production-level biosecurity measures.
- Is there a justification to allocate public resources for campaigns to control and eradicate endemic diseases?
- What methodologies can improve the implementation of animal disease control programmes that are assessed to be nationally economically profitable?
- In an animal health system what roles should the public veterinary services and the private sector play to improve the welfare benefits from animal disease control investments?
  - The improvements in animal disease status should take into account the needs of all socio-economic groups, poor and rich, producers and consumers.
  - It should be recognized that ideally each country would develop an animal health system according to its stage of development, cultural and social needs, rather than following models.
- At international level, where do responsibilities lie for the control of transboundary diseases? This is particularly relevant for countries that are poor and have the potential to export livestock products, but have difficulties in achieving OIE/WTO regulations to enter into attractive export markets.

It is difficult and in most cases impossible to separate science from economics in addressing animal health and disease problems. Epidemiology is so tightly mixed with economics that often one forgets to say epidemiological and economic analysis of a disease and its control. For example, costs and benefits of disease control influence the willingness to participate in surveillance programmes and disease control strategies, and trade influences the movement of livestock and livestock products, which in turn influences the spread and maintenance of diseases.

The Book Objective and Structure

The challenges and opportunities for the economics of animal health and production require a *holistic or systems perspective* which combines an analysis of the political economy, the economic incentives, the social acceptability and the technical feasibility of disease control measures and programmes. With this in mind, the book sets out to provide the theoretical and practical basis to assess livestock systems and animal disease control for farm, private enterprise and government policy through the provision of data collection and analysis methods and examples of their application in decision making.

Book structure

The book draws on an extensive review of the literature on animal health economics (Rushton, 2002) and experience in livestock issues in Europe, Asia, Africa and Latin America. It is the work of a number of authors who are well respected in their own fields of economics and have also made significant contributions to livestock and animal health economics. The book is divided into the following chapter and three major parts:

- History of livestock and animal health economics (Chapter 1);
- Theory and tools for the economics of animal health and production (Part I);
- A review of the application of economics to animal diseases and health problems (Part II);
- Economic analysis and policy making: examples from around the world (Part III).

Part I, on economic theory and tools, includes an explanation of production economics theory supported by a contribution by Professor Clem Tisdell. The following chapter provides an overview of data collection management and methods, which is supported by a contribution from Dr Rommy Viscarra. In Chapter 7, the main tools available for farm-level assessment are presented and the chapter is supported by Dr Alistair Stott's explanation of optimization methods and Dr Andrew James' contribution on models and data collection. Chapter 10 covers the main tools for the assessment of markets, the economy and value chains followed by Professor Martin Upton's review of the main economic assessment methods and Professor David Leonard's introduction to Institutional Economics. Chapter 13 presents the importance and influence of social and cultural issues with regard to livestock decision making, and Dr Alexandra Shaw presents a good framework to assessing the impacts of animal diseases in a wider society context that includes human health. Part I concludes with a chapter on the general analysis of livestock systems.

Part II, on the review of the literature of studies on the economics of animal health and diseases, has chapters that cover diseases which affect a range of livestock species followed by chapters on diseases that affect large ruminants, small ruminants, pigs and poultry. Part III has contributions from around the world on the applications of the economics of animal health and production to different problems, in research, production and policy.

It is not the intention of the author that this book be read from cover to cover; it is a reference text that will introduce readers to theories and methods which are required to assess change in the livestock sector and assist decision makers at all levels in making investments and deciding on future strategies and policies. The examples presented are largely from real situations and serve to illustrate that the economic analysis of animal health and production requires a multidisciplinary and systems approach. This reflects the reality that faces livestock producers, agrobusiness people and policy makers involved in the livestock sector.

Foreword

At a time when the world faces a period of major changes in animal production to meet rapidly accelerating demand for animal products, it is highly opportune that CABI should have commissioned this study of relevant economic techniques. It is appropriate too that Jonathan Rushton has been chosen to edit the study because at the start of his career – as I saw first-hand – he made a remarkable socio-economic study of the roles of livestock in Indian villages. This complemented a deep knowledge of modern dairy farming acquired during his childhood on the family farm in England, and later he has practised his abilities as a consultant on the small, medium and very large livestock systems of Latin America, Africa, Asia and Europe. The contributors too have been well chosen to focus their knowledge on particular aspects of the complex methodologies now available.

In the 1960s, when supplies of animal products frequently exceeded consumer purchasing power, studies on the value of disease losses attracted little attention. However, as livestock development schemes expanded, trade diversified and awareness of disease risks for both humans and animals built up, and the need for socio-economic appraisal techniques has become more and more urgent. The rapid evolution of recording and computing technology now enables fully integrated analyses which can reflect the social as well as the economic implications of changes in animal production and health for farmers, human communities, nations and whole regions of the world.

This book should prove extremely useful for everyone concerned with production and health policies and I feel sure it will gain the wide readership it deserves.

Peter Ellis OBE
Former director of VEERU

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I would like to thank my life-long mentors, my parents Bessie and Trevor Rushton, for continuing to teach me that learning never stops. I would like to thank my father for his generosity in providing the drawings for the book. My professional mentors are Peter and Mary Ellis, who skilfully guided me through the early stages of my career and have given regular inputs ever since. There are many teachers, colleagues and friends who have given support, guidance and encouragement at various times; in no particular order, these include: Chris Gilligan, Ruth Henderson, Ed Miller, Tahir Rehman, Martin Upton, Steve Wiggins, T. Gopal, Chengappa, Andrew James, Andrew Paterson, Alexandra Shaw, Peter Spradbrow, Clare Heffernan, Festus Murithi, Susan Ngongi, Steve Angus, Madelon Meijer, Hernán Rojas, Armando Gonzalez, Vitor Piçao, Jaime Romero, Nick Taylor, Joachim Otte, Anni McLeod, James and Anna McGrane, Gabriel Ayala, Robyn Alders, Simon Anderson, Andrew Dorward, Elaine Marshall, Kate Schreckenberg, Karin Schwabenbauer and Jémi Domenech. The contributors are recognized and thanked for their time and energy in developing their chapters.

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1 History of Livestock and Animal Health Economics

Origins of the Subject

The study of the economics of livestock and their associated diseases is relatively young in relation to other economic disciplines and has really grown out of the movement of the epidemiology of diseases that began in the 1960s and early 1970s. While it is recognized that some interest has been shown in developing ideas of livestock economics (Brown, 1979; Crotty, 1980; Gittinger, 1982; Simpson, 1988), the much larger contributions to thinking on the economics of livestock production systems and their associated chains have come from the animal health angle. This interest was generated by governments who were beginning the final stages of eradication of major diseases and also becoming aware of the economic impact of less dramatic diseases such as infertility and parasitism. These animal health initiatives coincided with the interest in the economic analysis of the use of public funds. Prior to this period, veterinary services had kept records of the costs and benefits of disease control without any detailed analysis.

In the mid-1960s, Peter Ellis and Heinz Konigshofer documented the information available from the veterinary services in the Food and Agriculture Organization/World Health Organization/World Organization for Animal Health (FAO/WHO/OIE) Animal Health Yearbook. In the following years, Bill R. Macallon and associates at the United States Department of Agriculture (USDA) made more comprehensive assessments of a number of specific diseases. From this point onwards a number of important schools of thought began to emerge.

Main schools of thought and their contributions to its development

This section will briefly examine the schools of thought identified, listing some of their contributions to knowledge and reasons behind their existence. The reference lists provide the major articles written by people identified. The following schools are identified:

1. Ellis, Morris, Hugh-Jones, Putt, James and Shaw at the Veterinary Epidemiology and Economics Research Unit (VEERU), University of Reading, UK;
2. Carpenter at the Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California, Davis, USA;
3. McInerney and Howe at the University of Exeter, UK;
4. Dijkhuizen at the Animal Health Economics, Farm Management Group, Department of Economics and Management, Wageningen Agricultural University, The Netherlands; and

5. Emerging schools Tisdell, Harrison and Ramsay at the University of Queensland, Australia; Perry at the International Livestock Research Institute (ILRI), Kenya; and Bennett at the University of Reading.

Reading: Veterinary Epidemiology and Economics Research Unit (VEERU)

Peter Ellis was the founder of the Veterinary Epidemiology and Economics Research Unit (VEERU) at the University of Reading and in many ways a pioneer in the subject of animal health economics. His interest in economics evolved from work on foot-and-mouth disease (FMD) in South America where he discovered that FMD epidemiology could not be separated from livestock prices and farm management systems. When Ellis returned to the UK, he worked at the Agricultural Economics Research Institute in Oxford and was introduced to benefit–cost analysis by Ian Little, the co-author of the *Manual of Industrial Project Analysis in Developing Countries* (Little and Mirlees, 1968).

In 1970, Ellis moved to the University of Reading where he began an analysis of classical swine fever (CSF) eradication in the UK with finance from the Wellcome Foundation and an agreement with the Ministry of Agriculture, Fisheries and Food (MAFF; Ellis, 1972a). This was the first study to apply cost–benefit analysis techniques to an animal disease appraisal. The success of this study led to the interest in carrying out a similar one for brucellosis eradication in England and Wales (Hugh-Jones *et al*., 1975). At this point Martin Hugh-Jones went to Reading for 2 years to work on this project.

During these early works on animal health economics in the UK, Roger Morris had been working at the Veterinary School of the University of Melbourne on various aspects of economics with particular emphasis on the economics of production disease. Ellis and Morris met at a meeting convened by WHO in 1970 in Geneva to discuss approaches to evaluating the control of zoonoses. Morris went to Reading on a sabbatical in 1972 where Ellis and Morris consolidated their views, which were presented at a follow-up workshop for WHO in Reading, in which Macallon also participated. This workshop produced a four- or five-page working document, which, though never formally published, was widely distributed as a guideline for international project evaluations.

Morris during his sabbatical also collaborated with UK-practising vets who were involved in Dick Esslemont's study of oestrus behaviour in dairy cows. Morris lent a computer program which was modified to become 'Melbread' and later the DAISY information system which provided the basis for assessing the loss from infertility.

Demand for help from the European Economic Council/European Union (EEC/EU) and support for research from the Overseas Development Administration of the British Government, now DfID, resulted in the development of an interdisciplinary team that was in 1975 designated as VEERU. The early contributors to this group were Andrew James (economist), Nick Putt (veterinarian), Alexandra Shaw (economist), Lindsay Tyler (veterinarian), Dick Esselmont (farm management), Tony Woods (statistician), Andrew Stephens (veterinarian), Richard Matthewman (animal production), Howard Pharo (veterinarian) and at a later stage James Hanks (animal production), Anni McLeod (economist) and Jackie Leslie (economist).

In 1975, an increasing number of research students encouraged VEERU to establish a formal training programme, which offered short courses in epidemiology and economics and could be combined with research leading to an MPhil or a PhD degree. Later a specific MSc was offered. Many students from all over the world have passed through these courses.

The VEERU policy was to develop teams through studies and collaborative projects in different countries and to build around them training schemes for middle management in veterinary and livestock services. These initiatives have been supported by ODA, German Aid, Danish Aid, the British Council, FAO, OIE and the World Bank and many other agencies and involved a continuing series of visits to countries in Latin America, Africa, the Middle East, the Indian subcontinent and Asia by various combinations of staff.

In 1976, Ellis invited all the professionals he knew who were interested in veterinary

epidemiology and economics to come to Reading for an exchange of ideas. About 80 people attended the meeting and the proceedings provided a reference document, which was very widely distributed (Ellis *et al*., 1978). The main result of that meeting was the creation of the International Society of Veterinary Epidemiology and Economics (ISVEE) and a plan to hold meetings every 3 years. Morris was elected Chairman and offered Australia as the venue for the next meeting. Shortly after this meeting, the Society for Veterinary Epidemiology and Preventive Medicine (SVEPM) was founded in the UK and similar societies were created in France and other countries.

Some of the key people in the work of VEERU apart from Ellis are described below:

- Martin Hugh-Jones, now at the Department of Epidemiology and Community Health, Louisiana State University, was seconded to the University of Reading to work on the study of the economics of brucellosis eradication in England and Wales. He has since specialized in geographic information systems (GIS), modelling diseases such as anthrax, anaplasmosis dermatophilis and trypanosomiasis (a list of his publications is available in the reference list). What stands out in the work of Hugh-Jones is the thoroughness of the research; the economic impact assessments he has been involved in are based on a deep knowledge of the production system and epidemiology of the disease.
- Roger Morris, now at Massey University, New Zealand, was working on the economics of livestock disease in Australia at the same time that Ellis began working on this subject in the UK. He went to Reading for a sabbatical year in 1972 where he completed his thesis for a Master's from the University of Melbourne. He did his PhD supervised by Ellis in which he explored complementary methodology including the applications of risk analysis and chaos theory. He is one of the leading veterinary economists in the world and was co-editor of a book on animal health economics (Dijkhuizen and Morris, 1997).
- Nick Putt was an important figure in the epidemiology and economics of trypanosomiasis in Nigeria and Zambia. He directed the study on trypanosomiasis in Nigeria and also coordinated and authored some sections of the International Livestock Centre for Africa (ILCA) manual on epidemiology and economics (see below). Unfortunately, he died in the prime of his career in 1995.
- Alexandra Shaw, now an independent consultant, specialized in the economics of trypanosomiasis and its control, using her experiences from western Africa to explore not just the impact of the disease at herd level, but also its impact on land use and the general economy. She was also the key economist in the ILCA manual, which was the first to detail livestock disease economics techniques in book form, and she has been an important figure in the training of veterinarians and livestock productionists in the use of economic techniques around the world. She has also used her extensive language skills to forge links with West African, French and German institutions working in the field of epidemiology and economics.
- Andrew James, currently Director of VEERU, worked on early assessment of FMD costs and their control, first in general terms and then with examples from India. His later work concentrated on east coast fever (ECF), tick and tick-borne disease economics, with a series of papers based on experimental work in Zambia, Zimbabwe and Kenya. This work was coordinated with Rupert Pegram and Bruno Minjauw. James has also given important inputs to discussions on rinderpest and animal recording systems. Finally, probably his major contribution has been to clarify the concepts of production and productivity. His pioneering modelling work looking at production systems and returns to feed use is the basis for much research in animal disease economics currently coming from the VEERU group. He also developed the database PANACEA.

Their major contributions were in the early use in scientific studies of:

- cost–benefit analysis techniques;
- herd models (CLIPPER and LPEC);
- herd monitoring systems (DAISY, EVA, MONTY, INTERHERD);
- promoting the use of economic techniques in planning processes; and
- examining economic impact across different levels of society.

Their approach was and remains in the much more practical field of the economic assessment of animal disease based on detailed knowledge of the production system and the epidemiology of diseases within the production system. This was not popular and remains unpopular with the pure economist (see a list of publications by McInerney in the reference list).

Tim Carpenter (Davis, California)

Tim Carpenter was another pioneer in the field of animal health economics during the 1970s. His early work was on *Mycoplasma gallisepticum* (Carpenter *et al*., 1979) and *Mycoplasma meleagridis* in turkeys (Carpenter, 1980). Carpenter was probably the first to examine the use of different economic analysis techniques in the study of diseases and their control such as:

- decision tree analysis (Carpenter and Norman, 1983; Carpenter *et al*., 1987; Ruegg and Carpenter, 1989; Rodrigues *et al*., 1990);
- microeconomic analysis of disease (Carpenter, 1983);
- simulation models to assess animal disease (Carpenter and Thieme, 1980);
- dynamic programming (Carpenter and Howitt, 1988);
- dual estimation approach to derive shadow prices for diseases (Vagsholm *et al*., 1991);
- estimation of consumer surplus (Mohammed *et al*., 1987);
- willingness to pay for vaccination (Thorburn *et al*., 1987);
- linear programming (Carpenter, 1978; Carpenter and Howitt, 1980; Christiansen and Carpenter, 1983);
- use of economic analysis to review subsidies to veterinary support institutions (Carpenter and Howitt, 1982); and
- the use of the cost–benefit analysis approach for selecting veterinary services (Zessin and Carpenter, 1985).

Carpenter has also been involved in economic analysis with more conventional economic tools such as financial and cost–benefit analysis (Carpenter *et al*., 1981a,b, 1988; Davidson *et al*., 1981; Kimsey *et al*., 1985; Mousing *et al*., 1988; Vagsholm *et al*., 1988; Sischo *et al*., 1990). He has contributed to the discussion on the difficulties and problems of veterinary economics (Carpenter, 1994) and has been an important figure in the teaching of animal health economics (Carpenter, 1979).

Carpenter's work has been based on very thorough knowledge of the production system and the epidemiology of the disease concerned. He has been involved in the study of a number of diseases. What sets his contribution to the subject apart from other economists and veterinarians has been his willingness to experiment with a wide range of techniques.

John McInerney and Keith Howe at Exeter University, UK

John McInerney, during his time at the University of Reading, had some contact with the VEERU group. However, as an economist he was unhappy with the more practical approach to animal health economics that this group presented. With Keith Howe at Exeter, McInerney began research on the more theoretical economics of livestock disease, developing largely conceptual models of farmer behaviour towards disease (Howe, 1985; McInerney, 1988, 1999; Howe *et al*., 1989; McInerney *et al*., 1992; Howe and Christiansen, 2004). They continued this approach and to some extent with Richard Bennett at the University of Reading, in trying to teach their veterinary colleagues what economists do and how they approach assessment of disease (Howe, 1992). However, their influence on the thinking of animal health economics has largely been limited to concepts and theory. Howe was involved in early assessments of overall disease losses in the UK (Beynon and Howe, 1975) and they have had some involvement in analyses of mastitis (McInerney and Turner, 1989), tuberculosis (McInerney, 1986, 1987; Bourne *et al.,* 2000; Morrison *et al*., 2000) and Aujesky disease (Willeberg *et al*., 1996). McInerney has also had some input into animal welfare economics (McInerney, 1991, 1994).

This group is credited as being the first to begin thinking about the conceptual framework behind the economic analysis of disease and its control. However, it should be noted that the conceptual framework that was developed by McInerney has recently been criticized by Harrison *et al*. (1999), a group of economists based at the University of Queensland, Australia (see below).

Alt Dijkhuizen (Wageningen, The Netherlands)

In the 1970s, Dijkhuizen began investigations into the costs of disease with Renkema, but particularly with an emphasis on mastitis (Dijkhuizen, 1977; Dijkhuizen and Renkema, 1977, 1983; Dijkhuizen and Stelwagen, 1981, 1982) and diseases that affect dairy cattle (Renkema and Dijkhuizen, 1979; Dijkhuizen, 1983a,b). He also investigated the economics of animal surgery (Breukink and Dijkhuizen, 1982; Rougoor *et al*., 1994) and production problems (Dijkhuizen, 1983a,b; Dijkhuizen *et al*., 1984, 1985; Sol *et al*., 1984; Joosten *et al*., 1988). He used these earlier studies to begin research on the use of economic analysis techniques for animal disease (Renkema *et al*., 1981; Renkema and Dijkhuizen, 1985; Berentsen *et al*., 1992b; Dijkhuizen *et al*., 1994, 1996, 1998; Buijtels *et al*., 1996; Horst *et al*., 1996; Rougoor *et al*., 1996; Jalvingh *et al*., 1998). This work culminated in a co-edited book on animal health economics (Dijkhuizen and Morris, 1997), of which full details are provided in the following section.

In addition, Dijkhuizen and his team, in particular Jalvingh and Huirne, have worked on the following diseases and disease problems:

- Pig disease economics (Dijkhuizen, 1987, 1989a), economics of pig fertility (Houben *et al*., 1990; Dijkhuizen *et al*., 1997b) and culling management (Scholman and Dijkhuizen, 1989); the particular diseases this group has worked on are: CSF (Horst *et al*., 1997a; Dijkhuizen, 1999; Meuwissen *et al*., 1999; Nielen *et al*., 1999; Mangen *et al*., 2001), porcine reproductive and respiratory syndrome in The Netherlands (Klink *et al*., 1991) and Porcilis APP (Dijkhuizen and Valks, 1997).
- Cattle problems and diseases they have particularly worked on:
  - reproductive economics in cattle and buffalo (Shah *et al*., 1991);
  - the economics of cattle lameness (Enting *et al*., 1997);
  - bovine respiratory diseases (Fels-Klerx *et al*., 1999);
  - economics of mastitis (Schakenraad and Dijkhuizen, 1990; Schepers and Dijkhuizen, 1991; Houben *et al*., 1993, 1994; Barkema *et al*., 1995; Rougoor *et al*., 1999);
  - paratuberculosis, particularly in The Netherlands (Benedictus *et al*., 1985, 1986, 1987; van Schaik *et al*., 1996);
  - leptospirosis (van der Kamp *et al*., 1990);
  - bovine diarrhoea virus (Wentink and Dijkhuizen, 1990; Pasman *et al*., 1994; Stelwagen and Dijkhuizen, 1998);
  - bovine spongiform encephalopathy (BSE; Geurts *et al*., 1997);
  - bovine herpes virus (Noordegraaf *et al*., 1999; van Schaik *et al*., 1999; Noordegraaf *et al*., 2000).
- FMD disease economics particularly with reference to control strategies at a time when Europe was contemplating changing a policy of annual vaccination to no vaccination and a stamping out policy (Dijkhuizen, 1988, 1989b; Berentsen *et al*., 1990a,b, 1992a,b); they also contributed to discussions on the veterinary regulation associated with FMD (Berentsen *et al*., 1991).
- Risk of exotic disease (Horst *et al*., 1997b) and the incorporation of risk analysis into economic analysis (Dijkhuizen *et al*., 1997a); within this work they looked at the possible use of insurance against the occurrence of contagious diseases (Meuwissen *et al*., 1997), risks of animal movements introducing contagious diseases (Vos *et al*., 1999) and the modelling of virus introduction with examples of CSF and FMD (Horst *et al*., 1999).
- Animal welfare, food safety and animal health economics (Dijkhuizen, 1998).

Dijkhuizen developed his work from using animal recording systems such as PORKCHOP and developing the use of decision support systems such as CHESS. The recording systems' work extended beyond the farm level with analysis of national recording systems.

His modelling inputs have been to develop models to assist decision makers at farm, national and region levels.

In summary, Dijkhuizen has concentrated on the intensive pig and dairy sectors of The Netherlands. His work has been mainly on the important contagious diseases such as CSF and FMD, production diseases such as mastitis and production problems such as fertility. This has largely been focused on the Dutch commercial sector. However, his experience has also been used to examine different techniques for the economic assessment of diseases and the use of economic and risk analysis tools to aid decision makers. His contributions in these areas have been important in directing animal health policies in his own country.

Emerging schools

TISDELL, HARRISON AND RAMSAY AT THE UNIVERSITY OF QUEENSLAND, BRISBANE, AUSTRALIA. During the 1990s, an animal health project in Thailand was supported by the economics department at the University of Queensland headed by Tisdell. This project provided material for research into the economics of livestock diseases and their control with a focus on FMD economics. Tisdell (1995) and Harrison (1996) examined the use of cost–benefit analysis for assessing animal disease programmes. It is the first school to have carefully examined and criticized the McInerney conceptual theory and was able to do so on the basis of practical experience and intellectual capacity. These economists also investigated how animal health programmes can help sustainable development (Harrison and Tisdell, 1997) with particular reference to Thailand. Ramsay, Tisdell and Harrison (1997a,b,c) also looked at how better information for animal health could improve decision making and how this affected the benefits from these improved decisions. This work was based on analysis of the FMD programme in Thailand (Harrison and Tisdell, 1999) and research work on control of *Babesia bovis* in Australia (Ramsay, 1997). The economists involved in this research published many of their ideas on animal health economics in the Australian Centre for International Agricultural Research (ACIAR) publication titled *Advances in the Collection, Management and Use of Animal Health Information* (Harrison and Sharma, 1999; Harrison *et al*., 1999; Ramsay *et al*., 1999a,b), and one of their main contributions has been to critically assess the conceptual models developed by McInerney on animal disease control. Their conclusions suggest that endemic diseases have two options: do nothing or eradication (Harrison *et al*., 1999; Tisdell *et al*., 1999). This view is based on the need for large fixed costs at the beginning of a programme, which initially have no benefits in terms of reducing disease losses, but are needed to lead to eradication of disease. If these initial fixed costs cannot be met, then there is no point in investing small amounts in the control of disease.

BENNETT AT THE UNIVERSITY OF READING, UK. Richard Bennett at the University of Reading has made contributions to the subject of animal health economics, initially with work on how to use information on animal health decisions (Bennett, 1991) and decision making for leptospirosis in cattle (Bennett, 1993). The main contribution of his work so far has been in the field of animal welfare economics (Bennett, 1995, 1998; Bennett and Larson, 1996; Blaney and Bennett, 1997; Anderson *et al*., 1999) and assessing the losses from endemic diseases in the UK (Bennett *et al*., 1997, 1999a,b; Bennett, 2000). His work on endemic diseases in the UK touches on the economics of impact and control of most of the diseases across a range of livestock.

PERRY, MUKHEBI, YOUNG, RANDOLPH, MCDERMOTT AND RICH AT THE INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE (ILRI), NAIROBI, KENYA. The epidemiology and disease control unit at ILRI in Kenya was led by Brian Perry. Perry is one of the world's most prominent epidemiologist with a depth of experience in a range of diseases. In the early 1990s, Perry worked on the economic impact of ticks and tick-borne diseases (Perry *et al.,* 1990). This work was with Adrian Mukhebi and concerned the economic assessments of ECF (Mukhebi *et al*., 1989, 1990) and theileriosis (Mukhebi *et al*., 1992). He also wrote a paper with Young on the epidemiology and economics of tick-borne disease (Perry and Young, 1995).

Recently, Perry has made other important contributions to the field of animal health economics. He coordinated the first book to bring together a number of important themes in animal health economics: farm-level economic assessments; trade implications of sanitary requirements; and veterinary service delivery (Perry, 1999). In addition Perry, with Tom Randolph and John McDermott, has written papers on epidemiology and economics (Perry *et al*., 2001), economics of parasitic diseases (Perry and Randolph, 1999) and has carried out major research into FMD economics (Perry *et al*., 1999). He was also involved in the economic assessment of heartwater (Mukhebi *et al*., 1999). More recently Karl Rich has joined the ILRI team and has made contributions on animal health economics, particularly in the area of complex modelling to capture the impacts of animal diseases and their control (Rich *et al*., 2005).

In addition to the list presented, the following people should be added, and groups or focuses are also identified:

1. Alistair Stott at Scottish Agricultural College (Stott, 2005) has pioneered the use of optimization methods in animal health decision making and the book includes a contribution from Dr Stott.

2. There have been investigations into veterinary service delivery and the use of New Institutional Economics by World Bank economists (Umali *et al*., 1992). David Leonard and Vinod Ahuja have taken this early work to new levels with fieldwork and analysis in Africa and India, respectively (Leonard, 2000, 2004; Ahuja, 2004). Some interesting work in Africa on this subject area has been carried out by Cheik Ly (Ly, 2003). David Leonard makes a contribution in the applications section of the book.

3. FAO pioneered early classification systems to detail how the livestock production units were developing and where they were concentrating (Steinfeld and Mäki-Hokkonen, 1995; Sere and Steinfeld, 1996). Building on these approaches, it was recognized that a livestock revolution was ongoing, responding to the growing demands of urban populations in developing countries (Delgado *et al*., 1999). It was documented at an early stage that much of the growth in the livestock sector was coming from the intensive monogastric systems and to some extent from a growth in milk production. For many reasons, these dramatic changes in livestock production were celebrated, some concerns were raised about poorer livestock producers being left behind (Haan *et al*., 2001; Heffernan, 2002; FAO, 2005; Owen *et al*., 2005) and issues on the potential negative impacts on the environment have been well investigated (de Haan *et al*., 1997; Steinfeld *et al*., 2006).

4. In FAO, there has also been the Pro-Poor Livestock Policy Initiative led by Joachim Otte investigating the use of a variety of economic methods. They have challenged the strong technical focus of animal health decision making and raised the need to see animal health problems as a mixture of policy, social and economic issues (FAO, 2007).[1]

Important references and books

With regard to the economics of livestock diseases some important books and papers are provided below:

- Putt, S.N.H., Shaw, A.P.M., Woods, A.J., Tyler, L. and James, A.D. (1988) *Veterinary Epidemiology and Economics in Africa*. A manual for use in the design and appraisal of livestock health policy. ILCA Manual No. 3, International Livestock Centre for Africa (now International Livestock Research Institute), Addis Ababa, Ethiopia.
  - This is the first book published on this subject and contains sections on 'The use of economics in the planning and evaluation of disease control programmes'; 'Estimating the costs of diseases and the benefits of their control'; and 'Economics and decision-making in disease control policy'. It also includes discussions of modelling techniques with an early example of the James' static herd model.
- McInerney, J.P., Howe, K.S. and Schepers, J.A. (1992) A framework for the economic

[1] http://www.fao.org/ag/againfo/projects/en/pplpi/

analysis of disease in farm livestock. *Preventive Veterinary Medicine* 13, 137–154.
  - First outline of conceptual ideas for animal health economics, which introduces the need for thoughts on costs of disease control not just losses caused by disease. This is the basis for improving decisions on diseases.
- Dijkhuizen, A.A. and Morris, R.S. (eds) (1997) *Animal Health Economics: Principles and Applications*. University of Sydney, Postgraduate Foundation in Veterinary Science, Sydney, Australia.
  - The book brings together much of the modelling work of the Dijkhuizen group with contributions from other world leaders in animal health economics. The book contains the following sections:
    1. Framework and basic methods of economic analysis:
       (a) 'How economically important is animal disease and why?' (Morris, pp. 1–11);
       (b) 'Economic decision making in animal health management' (Dijkhuizen; R.B.M. Huirne; Morris, pp. 13–23);
       (c) 'Basic methods of economic analysis' (Huirne; Dijkhuizen, pp. 25–39); and
       (d) 'Economic impact of common health and fertility problems' (Dijkhuizen; Huirne; A.W. Jalvingh; J. Stelwagen, pp. 41–58).
    2. Advanced methods of economic analysis:
       (a) 'Critical steps in systems simulation' (Dijkhuizen; A.W. Jalvingh; R.B.M. Huirne, pp. 59–67);
       (b) 'Linear programming to meet management targets and restrictions' (Jalvingh; Dijkhuizen; J.A. Renkema, pp. 69–84);
       (c) 'Dynamic programming to optimise treatment and replacement decisions' (Huirne; Dijkhuizen; P. van Beek; Renkema, pp. 85–97);
       (d) 'Markov chain simulation to evaluate user-defined management strategies' (Jalvingh; Dijkhuizen; J.A.M. van Arendonk, pp. 99–113); and
       (e) 'Monte Carlo simulation to model spread in management outcomes' (W.E. Marsh; Morris, pp. 115–133).
    3. Risky choice in animal health management:
       (a) 'Scope and concepts of risky decision making' (R.B.M. Huirne; J.B. Hardaker, pp. 135–147);
       (b) 'Application of portfolio theory for the optimal choice of on-farm veterinary management programs' (D.T. Galligan; W.E. Marsh, pp. 149–157);
       (c) 'Modelling the economics of risky decision making in highly contagious disease control' (Dijkhuizen; A.W. Jalvingh; P.B.M. Berentsen; A.J. Oskam, pp. 159–170);
       (d) 'Risk analysis and the international trade in animals and their products' (S.C. MacDiarmid, pp. 171–185).
    4. Decision support in animal health management:
       (a) 'Examples of integrated information systems for decision making at farm and national level' (Morris; W.E. Marsh; R.L. Sanson; J.S. McKenzie, pp. 187–199);
       (b) 'Profitability of herd health control and management information systems under field conditions' (Dijkhuizen; J.A.A.M. Verstegen; R.B.M. Huirne; A. Brand, pp. 201–207);
       (c) 'Disease control programs in developing countries: prospects and constraints' (B.D. Perry); and
       (d) 'How do we integrate economics into the policy development and implementation process?' (A.D. James).
    5. Use of spreadsheets in animal health economics:
       (a) 'Building a spreadsheet model' (Morris; C.W. Rougoor; R.B.M. Huirne, pp. 233–245); and
       (b) 'Computer exercises on animal health economics' (Rougoor; A.W. Jalvingh; Dijkhuizen; Morris; Huirne, pp. 247–305).

- In 1998 OIE commissioned an edition of their journal titled 'The economics of animal disease control' (Perry, 1999).
  - This edition of *Scientifique et Technique* contains information on economic analysis techniques from farm level through to consumer surplus analysis. In addition, it looks at the importance of veterinary service delivery and trade implications with greater global movement of livestock and livestock products. Finally the edition has case studies on: FMD; rinderpest; rabies control; BVD.
- Animal health work supported and funded by ACIAR during the 1990s was published in a monograph titled *Understanding Animal Health in South-East Asia – Advances in the Collection, Management and Use of Animal Health Information* (Sharma and Baldock, 1999).
  - This ACIAR publication contains important ideas developed by Tisdell, Harrison and Ramsay on animal health economics, benefits from animal health projects, integrating economics with GIS systems for animal health decisions and improving animal health decisions through better information.

The above publications provide the reader with a very good basis for beginning economic assessment of livestock diseases, covering the conceptual aspects of disease losses and control of diseases (McInerney *et al*., 1992; Harrison *et al*., 1999) and information on the methodologies and techniques for the analysis of diseases and their control (Putt *et al*., 1988; Dijkhuizen and Morris, 1997; Perry, 1999). In addition to these animal health economics texts, the papers by Upton (1989, 1993) and James and Carles (1996) on livestock productivity assessments are a very useful introduction to assessing livestock interventions and systems changes. Other overviews of the subject of animal health economics have been written by Rushton *et al*. (2007) and Howe and Christiansen (2004). The basis of the paper by Rushton *et al*. (2007) comes from the material presented in this section.

Summary

In summary, this chapter on the history of the economics of animal health and production demonstrates that it is a dynamic area of work and research. Doubts have been expressed whether this subject is a discipline (Howe and Christiansen, 2004), but it is clear that a small group of academics, consultants and other professionals are dedicated to investigating the economics of livestock systems and animal health problems associated with these systems. It is a relatively specialized area of economics in the sense that the underlying technical issues for livestock systems are very specific (Rushton *et al*., 1999; Part I). However, in contrast to the well-documented social and economic importance of crop diseases (Apple, 1978), the economic implications of animal diseases have been comparatively understudied (Rushton *et al*., 1999). McInerney (1996) urged that much more work be done in applying 'old economics' to the 'new problem' of livestock disease. In one sense, it seems extraordinary that livestock disease has still not been thoroughly explored within the analytical framework of production economics.

Rushton *et al*. (2007) also posed the question of whether the subject of animal health economics is moving and changing to meet the environment and challenges set by the livestock sector and society as a whole. In partial answer to this question, Part I will provide an overview of the theoretical basis for making assessments of animal health and production and introduce important data collection methods and practical tools. The intention is to provide the reader with an analytical framework to respond to the changing demands of society.