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Cost Benefit Analysis with Applications to
Animal Health Programmes: Basics of CBA

by

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**Cost-Benefit Analysis with Applications to Animal Health
Programmes: Basics of CBA¹**

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This is number one of a set of six papers by Dr S. Harrison on 'Cost-Benefit Analysis with Applications to Animal Health Programmes' to be published in this series Research Papers and Reports in Animal Health Economics.

Papers in this Set

1. Cost-Benefit with applications to Animal Health Programmes: Basics of CBA, Research Paper or Report No. 18.
2. Cost-Benefit Analysis with Applications to Animal Health Programmes: Complexities of CBA, Research Paper or Report No. 19.
3. Cost-Benefit Analysis with Applications to Animal Health Programmes: Spreadsheet Implementation of Discounted Cash Flow and Risk Analysis, Research Paper or Report No. 20.
4. Cost-Benefit Analysis with Applications to Animal Health Programmes: Allowing for Project Risk in CBA, Research Paper or Report No. 21.
5. Cost-Benefit analysis with applications to Animal Health Programmes: Valuation of Non-Market Costs and Benefits, Research Paper or Report No.22.
6. Cost-Benefit Analysis with Applications to Animal Health Programmes: Animal Health Programmes and Information Systems, Research Paper or Report No. 23.

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The Commissioned Organization is the Queensland Department of Primary Industries. Collaborating institutions in Australia are CSIRO-ANHL, Geelong, Victoria and the University of Queensland (Department of Economics; Department of Geographical Sciences and Planning). In Thailand, the collaborating institutions are the Department of Livestock Development (National Institute of Animal Health; Disease Control Division), Chiang Mai University (Department of Agricultural Economics; Department of Animal Husbandry) and Thammasat University (Faculty of Economics). The collaborating institution in Laos is the Department of Livestock and Veterinary Services. Dr F.C. Baldock, Senior Principal Epidemiologist, Queensland Department of Primary Industries is the Project Leader in Australia and Dr P. Chamnanpood, Senior Epidemiologist, Thai Department of Livestock Development is the Project Leader in Thailand. Professor Clem Tisdell and Dr Steve Harrison, Department of Economics, University of Queensland are responsible mainly for the economic component of this project.

'The overall goal of this project is to develop and evaluate the necessary tools to provide decision-makers with reliable animal health information which is placed in context and analysed appropriately in both Thailand and Australia. This goal will be achieved by improving laboratory diagnostic procedures; undertaking research to obtain cost-effective population referenced data; integrating data sets using modern information management technology, namely a Geographical Information System (GIS); and providing a framework for the economic evaluation of the impact of animal diseases and their control.

A number of important diseases will be targeted in the project to test the systems being developed. In Thailand, the focus will be on smallholder livestock systems. In Australia, research will be directed at the northern beef industry as animal health information for this sector of livestock production is presently scarce.'

For more information on *Research Papers and Reports Animal Health Economics* write to Professor Clem Tisdell (c.tisdell@economics.uq.edu.au) or Dr Steve Harrison, (s.harrison@uq.edu.au) Department of Economics, University of Queensland, Brisbane, Australia, 4072.

Cost-Benefit Analysis with Application to Animal Health Programs: Basics of CBA

ABSTRACT

This discussion paper is one of a series of six papers which brings together both cost-benefit analysis methodology and the problems and issues in evaluation of regional and national animal health programs. Cost-benefit analysis (CBA) is a powerful economic technique for evaluating public sector investments, evaluating proposed research projects and programs, estimating the economic impact of new regulations, predicting the economic impacts of resource exploitation and conservation programs, and a variety of other applications. Applying CBA to animal health issues is a challenging task which, with a few notable exceptions, economists have avoided. Economic approaches to the study of animal health have many similarities with economics of public health. Livestock industries are vital in many developing countries for their food, fibre and other products, export revenue earnings and provision of draft and transport. In addition to their private costs, livestock diseases and pests have important externality costs to communities and nations. Eradication of particular diseases can allow access to high-priced foreign markets. Effects of improved animal health can be subtle and may take a number of years to be fully realised. They present particular measurement difficulties. Studies of the economic desirability of animal health programs have frequently overlooked important cost and benefits items, for example, the benefits which accrue to consumers from lower prices and better quality meat products. Like it or not, cost considerations will continue to play a part in determining what animal health initiatives can be funded. Also, it is usually necessary to present a thorough economic evaluation to decision-makers when seeking funding. This paper examines the economic logic underlying such an analysis, and makes suggestions on how it can be carried out.

Keywords: Cost benefit analysis, animal health issues, Thailand,

JEL Classifications: Q16, Q12

Cost-Benefit Analysis with Application to Animal Health Programs: Basics of CBA

PREFACE

This discussion paper is one of a series of six papers which brings together both cost-benefit analysis methodology and the problems and issues in evaluation of regional and national animal health programs. Cost-benefit analysis (CBA) is a powerful economic technique for evaluating public sector investments, evaluating proposed research projects and programs, estimating the economic impact of new regulations, predicting the economic impacts of resource exploitation and conservation programs, and a variety of other applications. Applying CBA to animal health issues is a challenging task which, with a few notable exceptions, economists have avoided. Economic approaches to the study of animal health have many similarities with economics of public health. Livestock industries are vital in many developing countries for their food, fibre and other products, export revenue earnings and provision of draft and transport.

In addition to their private costs, livestock diseases and pests have important externality costs to communities and nations. Eradication of particular diseases can allow access to high-priced foreign markets. Effects of improved animal health can be subtle and may take a number of years to be fully realised. They present particular measurement difficulties. Studies of the economic desirability of animal health programs have frequently overlooked important cost and benefits items, for example, the benefits which accrue to consumers from lower prices and better quality meat products.

The material presented in this series of discussion papers was developed for a workshop on Cost-Benefit Analysis and Geographical Information Systems at Lampang, Thailand, on 24-27 January 1995. The workshop was conducted as part of Australian Centre for International Agricultural Research (ACIAR) project number 9204, titled 'Improved Methods in Diagnosis Epidemiology, Economic and Information Management in Australia and Thailand'. Project 9204 extended earlier ACIAR-funded projects on diagnosis and management of foot-and-mouth disease (FMD) in Thailand. The current project has focused on a range of diseases in cattle, buffalo, pigs and poultry. Also, active surveillance methods and a geographical

information system (GIS) are being trialled for disease monitoring in the north-west of Thailand, in the provinces of Lampang, Lamphun and Chiangmai.

Sessions at the workshop were rotated between cost-benefit analysis and geographical information systems, the latter being presented by Dr P.C. Sharma of the Department of Geographical Sciences and Planning at The University of Queensland. The GIS material is under preparation as a set of reports.

At the workshop, the economic rationale of cost-benefit analysis, use of spread sheet financial functions, estimation of costs and benefits of animal health projects and application of CBA to information systems were considered. The audience consisted mainly of government livestock officers and in particular veterinary epidemiologists. The material has therefore been designed for people with only limited knowledge of economics and limited skills in using computer spread sheets. Not all of the material developed in these papers could be covered in the four-day workshop, and some revisions and extensions have been made subsequent to the workshop.

It is felt that the material may be of wider interest to economists and veterinarians with an interest in planning introduction of new animal health programs. Like it or not, cost considerations will continue to play a part in determining what animal health initiatives can be funded. Also, it is usually necessary to present a thorough economic evaluation to decision-makers when seeking funding. This series of papers examines the economic logic underlying such an analysis, and makes suggestions on how it can be carried out.

The assistance of the Thailand Department of Livestock Development and in particular Dr Porchai Chamnanpood (coordinator of the ACIAR project in Thailand) in arranging the workshop is gratefully acknowledged.

Glossary of Anagrams

| | |
|--------|---|
| ACIAR | Australian Centre for International Agricultural Research |
| AHIS | Animal health information system |
| AHP | Animal health program |
| AIDAB | Australian International Development Assistance Bureau (now AusAID) |
| B/C | Benefit to cost (ratio) |
| CBA | Cost-benefit analysis |
| CDF | Cumulative (probability) density function |
| CEA | Cost-effectiveness analysis |
| DCF | Discounted cash flow (analysis) |
| DLD | Department of Livestock Development, Thailand |
| FMD | Foot-and-mouth disease |
| FSD | First stage stochastic dominance |
| GIS | Geographical information system |
| GPS | Geographic positioning system |
| IRR | Internal rate of return |
| LWRRDC | Land and Water Resources Research and Development Corporation |
| NFV | Net future value |
| NOAA | National Oceanic and Atmospheric Administration |
| NPV | Net present value |
| OV | Option value |
| SDA | Stochastic dominance analysis |
| TEV | Total economic value |
| UV | User value |
| WTP | (Consumer) willingness to pay |

Cost-Benefit Analysis with Application to Animal Health Programs: Basics of CBA

1. INTRODUCTION

This paper forms Part 1 of a series of six discussion papers examining various aspects of cost-benefit analysis of animal health programs provides an overview of the economic methods and issues involved in animal health studies. Part 2 examines a variety of complexities in the use of CBA. Spread sheet implementation of the technique is explained in Part 3, while in Part 4 methods of dealing with project risk such as sensitivity analysis and risk simulation are outlined. Part 5 discusses recent developments in the estimation of ‘non-market’ costs and benefits (sometimes referred to as intangibles). The application of CBA to animal health information systems is discussed and some concluding comments are made in Part 6.

The second section of this paper provides an overview of the role of cost-benefit analysis (CBA) in animal health studies. The microeconomic theory underlying is explained in the third section, with emphasis on concepts of producer and consumer surplus, as background to identifying relevant costs and benefits. The final section discusses essential elements of CBA methodology, including discounting and estimation of performance criteria.

2. OVERVIEW OF COST-BENEFIT ANALYSIS IN ANIMAL HEALTH

Any government animal health program (AHP) will involve public and private sector expenditures, and generate returns in terms of reduced costs or increased incomes over time. There may also be impacts of consumer prices of livestock products, animal welfare, export opportunities and other variables. When deciding whether to introduce a new animal health program, or planning its introduction and monitoring, it is important to have an understanding of the costs and benefits which are likely to arise.

Any form of applied microeconomics is concerned with the costs and the benefits of alternative policies for the management of some economic system (e.g. production activity, firm or industry). In other words, some type of cost-benefit analysis (CBA) is widely used, although often in implicit rather than explicit form. CBA provides the analysis logic and concepts even when not formally applied as an analysis ‘technique’.

CBA had its genesis in the economic evaluation of public sector watershed management projects involving large public sector outlays, in the USA in the 1960s. There its use was mandatory, and was designed to provide greater accountability in use of public funds. A major resurgence of interest in this methodology took place in the 1980s, associated with tighter public sector budgets and increased requirements of agencies to demonstrate the economic viability of their programs, and also with new developments in valuation of environmental and other non-market costs and benefits. The CBA approach is well suited to economic evaluation of large-scale public sector programs concerned with animal health, such as national vaccination and disease eradication programs.

This section is designed to introduce a number of the economic concepts and perspectives of applying economic analysis to animal health programs. Section 2 will introduce microeconomic concepts in more detail.

Cost-benefit analysis involves use of discounting techniques to derive various project performance criteria. In a more formal sense, CBA is a technique used to evaluate individual projects, or compare alternative projects, which involve costs and generate revenues over a number of years. This definition immediately raises the questions of what is a project, how are costs and revenues measured, how is time taken into account, and what criteria are used to evaluate or compare projects. Discounting concepts and the various criteria are introduced in Section 3, with reference to a simple worked example.

2.1 The perspective and role of the economist

Before examining aspects of CBA, it is useful to have some understanding of the perspectives and role of economists, and economic concepts of benefits and costs, and these will now be reviewed briefly.

Box 1: Economic perspectives

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|---|
| GENERATE QUANTITATIVE DECISION-SUPPORT INFORMATION ANTHROPOCENTRISM VERSUS OTHER PERSPECTIVES PROFIT MAXIMISATION MULTIPLE GOALS CONSTRAINT GOALS MULTIDISCIPLINARY TEAM |
|---|

Economists can play an important role by examining the economic implications of various alternative course of action, and pointing out these implications to decision makers. For example, an economist could say that a particular animal health program would cost 2b baht and lead to extra revenue of 5b baht, while another program would cost 3b baht and produce 7b baht in revenue. Decision makers (in this case government) can combine this economic information with other information (e.g. about national expenditure priorities, likely acceptance of programs to livestock owners) and judgement and intuition to arrive at a decision. In other words, the input of the economics is information to augment other information already held or being gathered by decision makers. Economists provide decision *support* information. Usually, economists do not make the decision, or take the consequences of that decision. But by pointing out the economic payoffs involved, they can assist managers in government or private enterprise to make better decisions.

Economists typically take an *anthropocentric* or human-centred approach. Goods and services are valued in terms of what people are prepared to pay for them. The principle of ‘consumer sovereignty’ is adopted, in which people are regarded as the best judge of what is good for them. This approach implies for example, that reduction in livestock disease incidence is worthwhile only inasmuch as people derive benefit from it. People often reject economics, arguing that other perspectives should govern decision-making. One alternative approach is a *biocentric* approach which would imply that life forms other than humans have rights independent of human goals and aspirations. Another alternative is *stewardship*, i.e. that humans have a responsibility to maintain biological resources and the environment in good condition for the benefit of future generations. This raises questions of whether man-made capital can substitute for natural capital. Sometimes, various social, religious and ecological goals are placed ahead of ‘economic rationality’. This should not be of great concern for economic analysis because, as pointed out above, economists can assist policy makers by pointing out trade-offs, to be balanced against other objectives in the political process. Further, if desired their analysis can incorporate these other objectives in the form of constraints placed on the range of options over which optimisation of economic performance can be pursued.

From an academic viewpoint, the economic objective is to maximise community ‘utility’ or satisfaction, which for producers is usually taken to be approximated by profit maximisation. However, profit is a short-term (annual) concept, and in the longer term firms will usually

want to maximise asset accumulation, minimise debt or risk of financial collapse, minimise the risk of takeover or optimise a variety of other goals. Often livestock producers place major emphasis on improving the quality of their stock (this becomes a goal in itself) which is not usually taken into account in economic analysis. In other words, producers typically have *multiple goals*. This can present problems for economic analysis, although frequently a number of the goals are simply treated as constraints.

As well as producers, it is necessary to take into account the welfare of consumers, and how this changes in response to government programs. For example, if an improvement in animal health can lead to better human health or reduced meat prices, then consumer welfare is increased.

Particularly where large public investment or conservation decisions are being considered, economists often work as part of a *multidisciplinary team*. To communicate effectively with other specialists, they need to have some appreciation of biology, sociology, planning, law and other areas. When working in such a team, it is tempting to become engrossed in other aspects of the project; but the economist has a responsibility to point out the *economic trade-offs* that are involved; if they do not then no-one will!

2.2 *Measures of community economic wellbeing*

Economists examine markets for commodities and services in terms of supply and demand relationships. They usually consider that the most correct measure of community economic wellbeing is the so-called *economic surplus*. This includes the *producer surplus* (approximating the profits of producers) and the *consumer surplus* (or consumer gain or 'profit') in a market. A change in the conditions of production (e.g. a change in animal health status) will lead to shift in supply of a commodity, with a consequent change in the overall economic surplus. This concept will be examined further in Section 2.

Box 2: Measurement of community economic wellbeing

| |
|---------------------------|
| SUPPLY AND DEMAND CURVES |
| MARKET EQUILIBRIUM |
| ECONOMIC SURPLUS |
| SHIFT IN SUPPLY OR DEMAND |

2.3 *Costs of livestock diseases*

Animal health programs are concerned with control of diseases and pests in livestock. (For convenience, some pests including internal parasites are usually grouped under the heading of diseases.) Livestock diseases give rise to a number of costs to a society (Box 3). The most obvious are the costs to producers, such as loss of production (meat products and yields of milk and eggs), reproduction, draft and transport. However, these are by no means all the costs, or even the major costs in many cases. A major improvement in animal health could have substantial benefits for the community as consumers of animal products. Considerable trade and development benefits can arise from improved animal health (Harrison and Tisdell, 1995).

Box 3: Costs of livestock diseases

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|---|
| PRODUCER COSTS GOVERNMENT COSTS CONSUMER COSTS NATIONAL COSTS (TRADE, DEVELOPMENT) |
|---|

2.4 *Animal health project costs and benefits*

Relevant costs include both the overhead costs of setting up an AHP and the recurring (operating) costs of maintaining that program over time. Program benefits include, but are not limited to, increases in annual revenue earned by producers. In particular, costs avoided are often included in the benefit stream. For example, if a disease eradication program leads to reduced costs of treating sick animals, this would be included as a program benefit. As noted earlier, any benefits to consumers of livestock products would also be relevant in evaluation of an AHP.

2.5 *The technique of cost-benefit analysis*

Cost-benefit analysis is a technique widely used to estimate the costs, benefits and net payoff to a society of specific public-sector initiative or 'program'. In essence, In CBA, cost and benefit streams over time are compared, and various performance criteria derived to determine whether the investment is socially desirable. Cost-benefit analysis is only one of a variety of techniques used by economists. However, as noted above, it is more than simply and analysis technique. Rather, it provides a framework for applied economic analysis of

policy issues, within which survey data collection and analysis, systems simulation, econometrics and other techniques can assist in provision of cost and revenue data.

Box 4: Aspects of cost-benefit analysis

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|---|
| DEFINITION CBA VERSUS COST-EFFECTIVENESS ANALYSIS SOCIAL VERSUS PRIVATE PERSPECTIVE COMMON UNIT OF MEASUREMENT DISCOUNTING AND PRESENT VALUES USE OF ELECTRONIC SPREADSHEET PACKAGES POLICY RELEVANCE |
|---|

An alternative approach is *cost-effectiveness analysis* (CEA) in which costs only are estimated in detail. Here, costs may be compared on a unit of physical benefit basis, e.g. dollars spent per beast vaccinated. Many infrastructure projects have clearly defined outputs, which will be more-or-less constant regardless of how they are brought about provided essential design specifications are met, and hence are candidates for CEA. Public health and animal health projects could fall into this class. For example, once a decision had been made to eradicate a particular livestock disease in a particular region or country, CEA could be used to compare alternative eradication strategies. Note however that CBA would be the relevant technique to use when determining whether it is in the national interest to eradicate the pest or disease in the first place.

Cost-benefit analysis is normally applied to public sector (government) projects, not investments in the private sector. Government agencies often carry out (or hire consultants to carry out) CBAs. These are performed for a number of reasons. The analysis may be needed to determine whether a particular program is worthwhile, or to compare alternative ways of carrying out the program, or to compare a program with expenditure in other areas. Also, it may be necessary for one department to demonstrate to another (particularly the Treasury) that a program should be funded, i.e. to justify the funding.

Discounting is the procedure used to reduce future amounts to the equivalents in today's currency (in both CBA and CEA). It is needed because of differences in timing of project costs and benefits. For example, major costs of a disease eradication program would be incurred 'up front', while benefits might not become apparent for a decade or more. When an

amount to be paid or received at some time in the future is discounted, a *present value* is obtained.

2.6 *The role of government in animal health*

Governments often fund animal health programs. Why should they (and indirectly all taxpayers), make this expenditure? Why should livestock owners not accept this funding as their responsibility?

Box 5: Reasons for public intervention in animal health

MARKET FAILURE
GOVERNMENT INTERVENTION
OPTIMAL EFFORT LEVEL FOR DISEASE CONTROL
OPTIMAL MIXTURE OF PREVENTION AND CONTROL

The public sector (i.e. government) often needs to take actions in animal health because the effort (expenditure) made by the private sector would not be sufficient to achieve disease control. This could be the case because some of the benefits of improved animal health are not captured by producers, e.g. there may be externalities or spillover effects to the community say in terms of increased health and nutrition. Even when it would be in the self-interest of the private producers collectively to make the expenditure, many may not wish to do so individually for fear others will not also contribute. Another case is where the initial expenditure is too great for individual producers to finance, and only the government can command the resources necessary. As well, there may be a need to have compulsory measures, for which compliance is expensive and unpopular with some livestock owners, and only a government can make the measures mandatory. A case in point is vaccination against a disease such as FMD, which is effective only if there is a high adoption rate. Finally, only a government livestock department may have the veterinary expertise and organisational ability to implement a large-scale animal health program. In these various cases of *market failure*, there is often justification for a government to invest in animal health programs. Where public health is involved, such investment may be considered a community service obligation (CSO) of government.

In some cases, it would simply not be worthwhile for a government to spend large sums on trying to eradicate or reduce the incidence of a disease. This would be the case for example in some countries where there are at present only rudimentary veterinary services, so that the

program would be exorbitantly expensive and have little chance of success. Even in countries with well-developed animal health infrastructure, the decision is often made to ‘live with’ rather than eradicate a particular disease or pest, e.g. FMD in some countries, cattle tick in Australia. Hence the amount of effort or expenditure involved in any proposed animal health program has to be considered in terms of the costs and benefits it involves.

For any country at any time, there exists an optimal level of intervention an optimal mix of intervention methods, and these may vary between regions. Optimal animal health policies will also vary depending on international agreements, e.g. international funding is made available for some priority diseases. If OECD and OIE (the international veterinary epidemiology organisation) allow particular regions within countries to be classified as free of particular diseases for trade purposes, and this is accepted by meat importing countries, then there can be economic justification for greater effort to achieve disease free status in regions where the disease is most easily eliminated.

2.7 Government intervention measures

Governments can use a range of intervention measures to improve animal health. In general these can be direct expenditure, regulations, extension, taxation and market-based measures. More specifically, these can take forms such as listed in Box 6.

Box 6: Animal health program measures

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|--|
| VETERINARY SERVICES INFORMATION SYSTEMS VACCINATION CONTROL OVER LIVESTOCK MOVEMENTS EXTENSION STAMPING OUT |
|--|

Some measures involve considerable public expenditure, e.g. increase in veterinary services, production of vaccines and provision of other infrastructure (diagnostic laboratories, road inspection stations). Some such as new regulations may be unpopular with producers and costly to enforce. Others such as increased extension effort to convince producers to improve management are labour intensive and not always highly effective. ‘Stamping out’ or destroying any animals diagnosed as having a particular disease (or even animals which may have come in contact with diseased animals) is usually only adopted to control new outbreaks

in areas though to be free of the disease. Usually, a mixture of the various measures will be desirable.

2.8 *Design of animal health programs*

Various factors will affect the design of animal health programs (Box 7). Perhaps most important are national priorities and policies with respect to livestock industries. The design of programs will depend on budgetary and other constraints, and on the information available to decision makers. This is why modern information technology (including geographical information systems (GIS)) have an important role to play in animal health information systems. CBA also is an approach for provision of information to decision makers.

Box 7: Animal health program design considerations

| |
|--|
| NATIONAL POLICIES AND TARGETS REGIONAL VARIATIONS BUDGETARY AND OTHER CONSTRAINTS INFORMATION SYSTEMS |
|--|

2.9 *Performing CBA on animal health programs*

For CBA, data have to be collected from a variety of sources; these include data at the producer level, at the government expenditure level and relating to potential trade benefits. The data are used to budget out annual cash flows, which are then subject to *discounted cash flow (DCF)* analysis, usually on a computer spreadsheet. As well, various forms of testing the reliability and robustness of DCF results are applied, e.g. sensitivity analysis, risk analysis.

Box 8: The CBA procedure for animal health programs

| |
|-------------------------------------|
| VILLAGE SURVEYS |
| DYNAMIC LIVESTOCK SIMULATION MODELS |
| ANALYSIS OF MARKET POTENTIAL |
| COSTING OF PROGRAM MEASURES |
| ANNUAL NET CASH FLOWS |
| DCF ANALYSIS BY SPREADSHEET |
| SENSITIVITY ANALYSIS |
| RISK ANALYSIS |

The discounted cash flow analysis yields a number of performance criteria by which to judge the economic acceptability of any particular animal health program or to compare the relative economics merits of two or more programs. While benefit-to-cost or B/C ratios might be expected to be the logical outcome of cost-benefit analysis, in practice other criteria such as net present value, internal rate of return, payback period, benefit-to-cost ratios and peak deficit are often calculated. These various measures are discussed in Section 4.

3. MICROECONOMIC THEORY UNDERLYING COST-BENEFIT ANALYSIS

Cost-benefit analysis has strong theoretical underpinnings in microeconomics and welfare economics. An understanding of some background economic concepts is necessary if the technique is to be used correctly. Situations frequently arise where decisions have to be made about what variables to include in an analysis, and how the variables should be measured. To answer these questions correctly, it is necessary to understand the economic logic upon which the technique is based.

3.1 *The laws of supply and demand*

In general terms, microeconomics is that area of economics dealing with individuals and firms, as distinct from overall national economies (called macroeconomics). The important microeconomic concept to grasp is the economic surplus, which is the change in overall economic wellbeing of producers and consumers in a community or country as a result of a policy change, such as increased effort on animal health.

The starting point for a discussion of microeconomic theory is the *market*. In a market, producers and sellers come together to trade in a particular product. An example would be a

saleyard where buffalos are sold in Lampang province. For convenience, we will consider a single and homogeneous product (buffalos for meat), and ignore marketing costs (transport, yard dues, agents fees).

In a market, those who supply a good come together with those who have a demand for that good. Economic theory asserts propositions or ‘laws’ about supply and demand. The law of supply states that the quantity of any particular good or service an individual producer (supplier) will be willing to sell in a particular time interval increases as price increases. This is best illustrated by way of a diagram. In Figure 1, price on the vertical axis is graphed against quantity on the horizontal axis. The line labelled S, representing the supply schedule, slopes upward to the right. According to this supply ‘curve’ or line, a livestock producers would be willing to place some animals on the market at low prices, as indicated towards the left hand end of the curve¹. To justify expanding production and supply, the producer would require higher prices, i.e. price must rise to attract increased quantity. At price p_1 quantity q_1 is supplied; when the price increases to p_2 the quantity offered increases to q_2 .

Economic theory suggests that a *producer’s supply curve* is that producer’s *marginal cost* curve, i.e. the schedule of extra cost of providing an extra unit of production, e.g. an extra animal for market. The logic is that if the price were sufficient to warrant the extra or marginal cost of producing another unit, it would be rational for the producer to do so.

If production costs were to fall, as would be the case with reduced disease incidence, the producer could supply the same quantity for a lower market price. If less had to be spent on animal health, the cost would fall for a given output. Viewed another way, output would increase for the same costs level, i.e. there would be a shift to the right in the producer’s supply curve.

¹ There is no particular reason why the supply schedule should follow a straight line, and in practice a curve would be more realistic, but straight lines are adequate for explaining the economic concepts and so will be used in the diagrams for convenience.

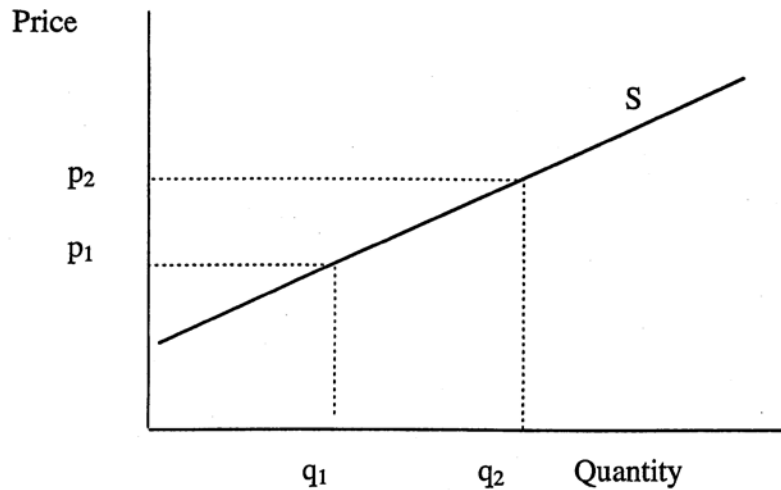


Figure 1 An individual producer's supply curve

The market supply curve is the sum of the individual producers' supply curves, and is of the same shape. The market could be a local livestock market, or the market for a province or country. The units on the quantity axis of course change as the market size changes. If there is a shift to the right in the supply schedule for the typical producer, there will also be a shift to the right in the market supply curve. This is illustrated in Figure 2, where animal health measures shift the market supply of an animal product from S to S_1 .

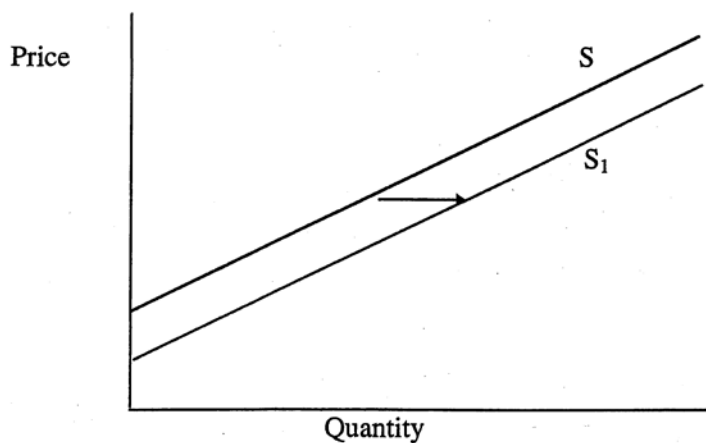


Figure 2 Rightward shift in market supply due to improvement in animal health

The 'law' of demand states that as price of a good or service falls, consumers will purchase more of it. (This applies to a particular market and particular period of time.) The increase in demand by an *individual consumer* arises both because at a lower price the particular good becomes more attractive than substitute goods (the *substitution effect*), and because as price

falls the consumer is able to afford more of it (the *income effect*). An illustration is provided as Figure 3, where the demand curve D implies that quantity demanded increases as price falls, i.e. the consumers demand curve slopes down to the right. This of course means that if price of a commodity such as beef or pork falls, a consumer will tend to consume more of it. For example, if price falls from p_1 to p_2 , a consumer's demand will increase from q_1 to q_2 .

The *market* demand curve is the sum of the demand curves of all individual consumers in a market, and is of the same shape as the individual consumer demand curve, but with a different scale on the quantity axis.

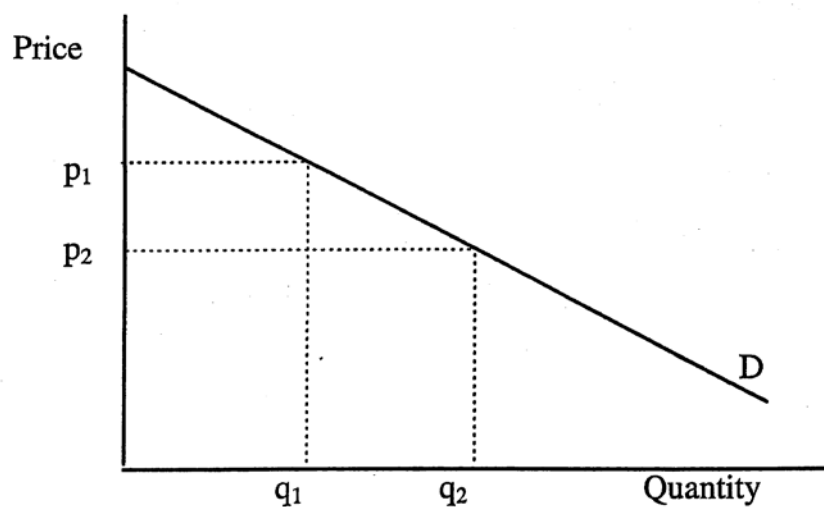


Figure 3 An individual consumer's demand curve

Just as the industry supply curve can shift left (decrease in supply) or right (increase in supply), so can the community demand curve. A change in tastes or in incomes could cause a shift. For example, if people developed a taste for more meat products in their diet, or could afford more livestock products, this would lead to a shift to the right in the demand for livestock. Also, if new inter-regional or export markets opened up, this would lead to a shift to the right in demand, because the overall market size (number of consumers) would increase.

The market supply and demand curves may be drawn on the same diagram, as in Figure 4. Where the two curves intersect, the quantity producers are willing to supply and the quantity consumers wish to purchase are equal. The corresponding price, labelled p , is the *market*

clearing price, and there is no unsatisfied supply or demand. At this price, q units are sold.

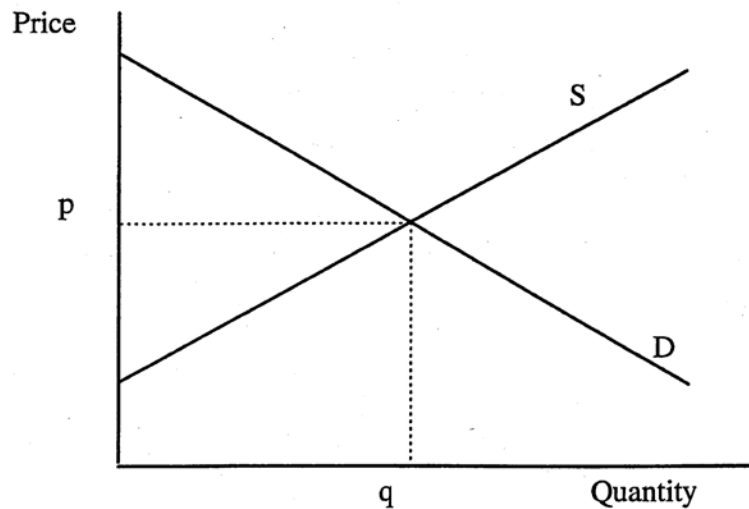


Figure 4 Market equilibrium, where supply equals demand

3.2 Elasticity of supply and demand

An important characteristic of supply and demand curves is their ‘elasticity’. The *elasticity of supply* with respect to price is the percentage change in quantity supplied for a one percentage point change in price. The *greater* the price elasticity of supply, the *flatter* the supply curve. The *elasticity of demand* with respect to price is the percentage change in demanded in a market in response to a one percentage point change in price. Again, elastic demand approximates to a relatively flat demand curve.

Economists distinguish between long-run and short run supply and demand. The long run is the shortest period of time in which livestock producers can expand their production facilities (perhaps two to five years). Elasticity, particularly of supply, is likely to be much larger in the long run than in the short run. While land constraints could prove an obstacle to increases in beef production, for intensive livestock such as pigs and poultry it is likely that other resources (capital, feed stocks) and environmental approvals will limit expansion in response to improved prices.

3.3 Economic surplus

Having covered this rather abstract economic theory, we are now ready to consider the concept of economic surplus, which provides the economic rationale for much of the economic analysis of animal health issues, e.g. Berentsen et al. (1992). With reference to

Figure 5, since the market price is p , consumers pay this price for all units purchased. However, consumers would have been prepared to pay a much larger amount for the first few units purchased (near the left-hand end of the demand curve). Also, consumers are not homogeneous, and some would have been willing and able to pay higher prices than others. The area of the triangle under the demand curve but above the price line represents an amount of money consumers save relative to what they would have been prepared to pay collectively for the quantity of the product traded. This area is known as the *consumer surplus* or *consumer profit*. (Note that areas in the diagram represent the product of price on the vertical axis and quantity on the vertical axis, and therefore represent values or amounts of money.)

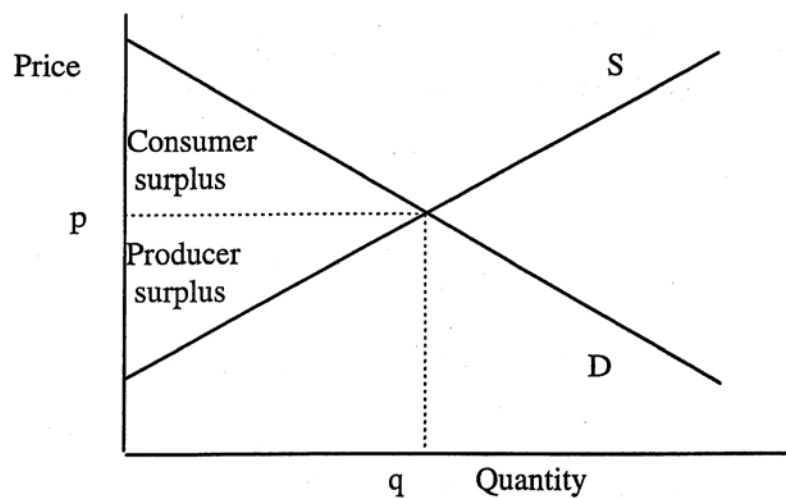


Figure 5 Producer and consumer surplus

Consider now the aggregate or industry supply curve. Even at very low prices, producers would be prepared to place some goods on the market, particularly the low-cost producers. Provided the price is greater than that at which the supply curve hits the price axis, some supply will be forthcoming. At a somewhat higher price (but still below p), producers would be prepared to supply a larger amount. If producers receive the price p for all units they supply, then they are receiving an amount above that which would have been necessary to call forth supply. The difference - represented by the area of the triangle above the supply curve but below the price line - is the *producer surplus*. If the supply curve corresponds to the marginal production cost curve, then the area is in fact the profit earned by producers in the market. The consumer surplus and producer surplus together make up the *economic surplus*. This is a measure of aggregate community gain from a market.

3.4 Effect of a shift in supply on economic surplus

Suppose improved animal health leads to a shift to the right in supply, as in Figure 6. What then happens to the producer and consumer surpluses? The shift in supply leads to a new equilibrium price p_1 and quantity q_1 . The consumer surplus clearly is increased, since a new area (between the lines p and p_1) is added. For the producer surplus, an area between the price lines p and p_1 is lost. However, the new producer surplus triangle both has a greater height (the distance between the new intercept on the price axis and p_1) and is longer (up to q_1 rather than q), and so has a greater area, i.e. producer surplus is increased. Overall, there is an increase in economic surplus, or in community welfare.

The share of the gain from a shift in supply between producers and consumers will depend on the elasticities of supply and demand. If demand is highly elastic (steep demand curve), a large increase in supply will lead to a large fall in price, to the benefit of consumers rather than producers.

Figure 6 illustrates a very important point. A decline in livestock owners' production costs leads to a gain or 'profit' not only to producers but also to consumers. In fact, consumers can be the main beneficiaries. This fact is often lost sight of in economic analysis on animal health programs.

3.5 Economic surplus for internationally traded commodities

The eradication of a livestock disease, and international acceptance of disease-free status, can open up lucrative export markets for a livestock product. For commodities which are internationally traded, the demand curve represents both domestic and foreign demand. In Figure 7, D_D is the domestic demand curve while D_T is the total demand curve (domestic plus foreign). The market equilibrium is determined by the intersection of total demand and domestic supply. At the equilibrium price p , q_D is domestic consumption, q_T is total consumption, and the difference q_T less q_D is exports.

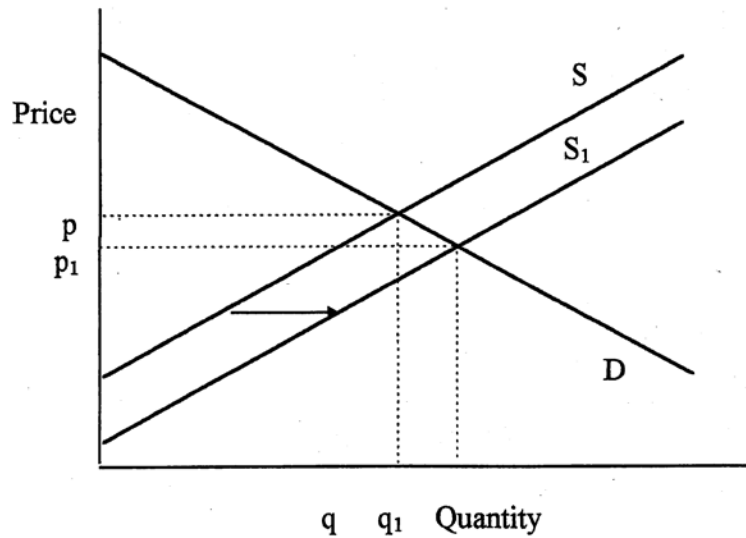


Figure 6 Change in economic surplus due to rightward shift in supply

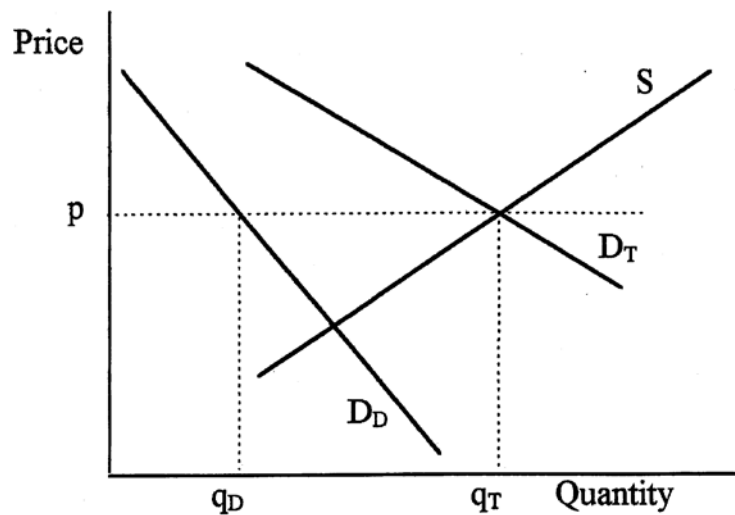


Figure 7 Economic surplus for an internationally traded commodity

Where a product is traded internationally, cost-benefit analysis would normally be carried out from the domestic viewpoint only. That is, the impact of an AHP would be assessed in terms of producer surplus plus the consumer surplus of domestic consumers only. The change in these values is not explored in detail here (a more comprehensive analysis is provided by Harrison and Tisdell, 1995). However, it is apparent from Figure 7 that addition of export demand substantially raises the equilibrium price. That is, producers will receive higher

prices and domestic consumers will be required to pay higher prices: the producer surplus will be positive, while the domestic consumer surplus will be negative.

This above analysis is somewhat simplistic. It assumes equality of prices in the domestic and export market. In practice, the price received in a foreign market will be higher than the domestic price, since the markets will to some extent operate independently of each other, and transport costs and quality differences also affect prices. Foreign demand is likely to be shaped to some extent by various restrictions on trade, e.g. quotas, tariffs. However, the analysis illustrates clearly that trade is likely to benefit producers but increase prices which consumers have to pay. In evaluation of the AHP, it is important to take into account these adverse consumer impacts.

4. ESSENTIALS OF CBA METHODOLOGY

This section examines the methodology of cost-benefits analysis in terms of data requirements, estimation of cash flows, and performance criteria and their usefulness. This chapter, and the one which follows, covers essential technical detail one needs to know, to be able to apply CBA.

4.1 Projects and programs

Cost-benefit analysis (CBA) is used to evaluate the economic desirability of an investment activity. The investment is sometimes referred to as a *project or a program*, and these two terms are often used interchangeably. However, at least two common distinctions in usage occur. If a new initiative is being undertaken by a government, it is usually referred to as a program. On the other hand, if a research effort is being undertaken (even a large- scale one), it is often referred to as a project. That is, governments have programs while researchers have projects. In this context, we may refer to a government *animal health program or an ACIAR research project*. Another distinction sometimes adopted is that a project is a specific activity carried out by a single person or group, while a program is a collection of related projects with some form of overall coordination. This is the definition adopted, for example, by the Australian Land and Water Resources Research and Development Corporation (LWRRDC) which funds a dryland salinity research program consisting of many separate *program projects*. It is no wonder there has been confusion between the two terms! When reference is being made to investment activities in general, the term ‘project’ will be adopted here (e.g.

‘project appraisal’), but government investment in animal health will be described as a ‘program’.

4.2 *The timing of CBA*

CBA is normally applied to a *proposed* project before it is accepted for implementation, referred to as *ex ante* analysis. The analysis is designed to determine whether the project is worthwhile in economic terms, and hence a justifiable use of public funds. Sometimes an *ex post* (or after-the-event) CBA is carried out, the purpose usually being to determine whether the project has lived up to expectations. As well, CBA calculations may be reworked periodically as a project proceeds, referred to as a *life-of-project evaluation*. The latter approach is obviously more demanding of resources, but is useful for public accountability, improving the analysis procedure, project monitoring, and determining what features characterise successful projects (picking winners). In Australia, LWRRDC are applying life-of-project evaluation to a representative sample of the projects they fund (Harrison and Tisdell, 1996). The emphasis here is on *ex ante* CBA.

4.3 *Private sector and public sector projects*

Investment projects are carried out by both the private and the public sector. In the private sector, a firm may wish to adopt new technology, purchase new equipment, purchase additional breeding stock, introduce a new intensive livestock enterprise, comply with new environmental regulations, or a host of other activities. These types of investments involve substantial initial capital outlays, with the return perhaps delayed but extending for many years into the future. Similarly, a government (local, regional or national) may wish to undertake an investment which has a long-term payoff, such a construction of a diagnostic laboratory, vaccine production plant or network of roadside inspection points, or to install a nation-wide animal health information system. Many public sector projects are in fact of an *infrastructure* type, such as construction of buildings, roads and communications, which have little direct payoff but indirectly enable revenue to be earned.

While CBA is relevant to both private sector and public sector projects, it is more commonly applied to the latter. In fact, most of the developments in CBA methodology have been designed for dealing with government programs. This is because CBA is an effective means to factor into the analysis social costs and benefits, e.g. on health, employment and income distribution. For this reason, the term "social" as applied to costs and benefits includes both

economic and more narrowly defined social impacts. In fact, the term ‘*social* cost-benefit analysis’ is often used. In recent years, considerable attention has also been paid to factoring environmental costs and benefits into CBA.

When carrying out a CBA it is important to clearly define the perspective of the analysis. A different approach is adopted for public sector projects relative to private sector projects. For the latter, only those costs and returns affecting the firm are relevant. For the former, all impacts on the community need to be taken into account. Also, some of the costs and benefits are valued differently. To take one example, taxation payments should be deducted when estimating the private profitability of an investment; they are not receipts retained by the firm. But for public sector projects, taxation payments are not a net gain or loss to society; rather, they are money transferred from the individual income earner to the public purse, referred to as *transfer payments*. Thus, taxation payments can be ignored when determining social benefit streams.

When carrying out a social CBA, it is still necessary to determine costs and benefits to private operators (e.g. livestock owners), but adjustments must be made such as removing transfer payments before these are aggregated and combined with public sector costs and benefits.

4.4 *Project revenues and costs*

With regard to identification of benefit and cost categories, two general principles should be noted:

Revenue earned and costs avoided. Any revenue earned as a result of investment in a project relative to that which would have been earned if the project were not to be implemented is, obviously a project benefit. However, any expenditure which would have been incurred in the absence of a project but are not necessary as a result of the project is, equally, project benefits. For example, saving in recurrent vaccination costs and veterinary expenses for sick animals would be a benefit from an animal health program.

Explicit and implicit costs. It is obvious that out-of-pocket or explicit costs such as wages, electricity charges, costs of veterinary medicines and payments for purchased stockfeeds should be attributed to a project. What is not so apparent is that allowance should be made for *opportunity costs* or *implicit costs* such as the value of a landholder’s own labour, financial

capital (savings in the bank) and buildings for which no actual payments are made, when these are used to support a project. As discussed later, in CBA the relevant cost categories are not always obvious, and considerable care must be taken in choosing which costs to attribute to a project.

4.5 Cost and benefit time patterns

Projects typically incur costs and generate revenues over a number of years. Often, large capital outlays are involved in the first few years of project life, but increases in revenue may not take place immediately and revenue may increase over several years. Figure 8 illustrates a typical pattern of project costs and benefits over time.

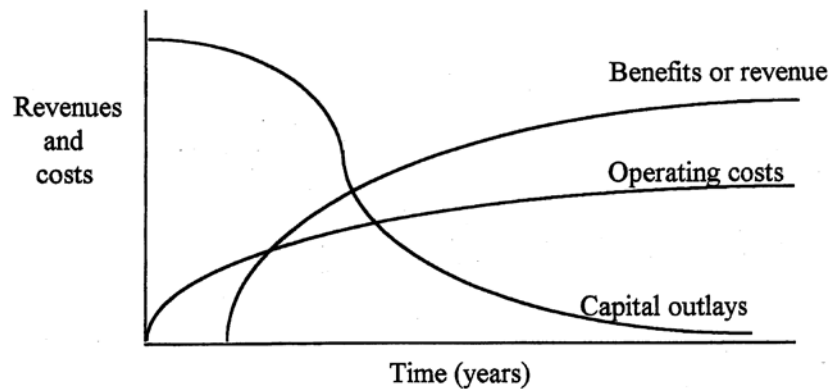


Figure 8 Typical time pattern of project costs and benefits

Static rate of return measures such as 'per cent return on capital' are sometimes used as criteria for investment profitability. However, when an investment is undertaken, the rate of return on capital may be negative for the first few years, increasing as income increases. In such cases, per cent return on capital fails to provide an adequate single index of project profitability. To consider only the rate of return when income has stabilised fails to take account of the differences in timing between project income and project expenditures. Rather, it is necessary to introduce discounting to bring costs and benefits to a comparable basis with respect to time.

4.6 Compounding and discounting

Before defining criteria to measure project performance, it is necessary to introduce some basic concepts and procedures with respect to compounding and discounting. Let us begin

with the concepts of simple and compound interest. For the moment, consider the interest rate as the *cost of capital* for the project.

Suppose a person has to choose between receiving \$1000 now, or a guaranteed \$1000 in 12 months' time. A rational person will naturally choose the former, because during the intervening period he or she could use the \$1000 for profitable investment (e.g. earning interest in the bank) or desired consumption. If the \$1000 were invested at an annual *interest* rate of 8%, then over one year it would earn \$80 in interest. That is, a *principal sum* of \$1000 invested for one year at an interest rate of 8% would have a *future value* of

$$\$1000 (1.08) = \$1080$$

The \$1000 may be invested for a second year, in which case it will earn further interest. If the interest again accrues on the principal of \$1000 only, this is known as simple interest. In this case the future value after two years will be \$1160. On the other hand, if interest accrues on the whole \$1080, known as *compound interest*, the future value will be

$$\$1080 (1.08) = \$1166.40$$

Investment and borrowing situations almost always involve compound interest, although the timing of interest payments may be such that all interest is paid before further interest accrues.

The future value of the \$1000 after two years may alternatively be derived as

$$\$1000 (1.08)^2 = \$1166.40$$

In general, the future value of an amount $\$a$, invested for n years at an interest rate of i , is

$$\$a (1 + i)^n$$

where it is to be noted that the interest rate i is expressed as a decimal (e.g. 0.08 and not 8 for an 8% rate).

The reverse of compounding - finding the present-day equivalent to a future sum - is known as *discounting*. Because \$1000 invested for one year at an interest rate of 8% would have a value of \$1080 in one year, the *present value* of \$1080 after one year, when the interest rate is 8%, is

$$\$1080/1.08 = \$1000$$

Similarly, the present value of \$1000 to be received in one year, when the interest rate is 8%, is

$$\$1000/1.08 = \$925.93$$

In general, if an amount \$a is to be received in n years' time, and the annual interest rate is i , then the present value is

$$\$a / (1 + i)^n$$

Since the interest rate is used in discounting future sums, it is also referred to as the *discount rate*. Also, terms of the form $(1 + i)^n$ are referred to as *discount factors*.

The above discussion has been in terms of amounts in a single year. Investments usually incur costs and generate income in each of a number of years. Suppose the amount of \$1000 is to be received at the end of each of the next four years. If not discounted, the sum of these amounts would be \$4000. But suppose the interest rate is 8%. What is the present value of this income stream? This is obtained by discounting the amount at the end of each year by the appropriate discount factor then summing:

$$\begin{aligned} & \$1000/1.08 + \$1000/1.08^2 + \$1000/1.08^3 + \$1000/1.08^4 \\ &= \$1000/1.08 + \$1000/1.1664 + \$1000/1.2597 + \$1000/1.3605 \\ &= \$925.93 + \$857.34 + \$793.83 + \$735.03 \\ &= \$3312.13 \end{aligned}$$

The discount factors - $1/1.08^t$ for $t = 1$ to 4 - may be derived on a calculator, read from published tables or generated on a computer spreadsheet. It is to be noted that the present value of the equal annual amount of \$1000 is progressively reduced for each year further into the future (from \$925.93 after one year to \$735.03 after four years), and the sum is approximately \$700 less than if no discounting (a zero discount rate) had been applied.

4.7 Discounted cash flow analysis

The interest rate procedures discussed above form the basis for what is known as discounted

cash flow (DCF) analysis. Any project may be regarded as generating cash flows, where the term cash flow refers to any movement of money to or away from an investor (an individual, firm, industry or government). Projects require payments in the form of capital outlays and annual operating costs, referred to collectively as cash outflows. They give rise to revenues or cost savings, referred to as project benefits or cash inflows. For each year, the difference between cash inflows and cash outflows is known as the project's net cash flow. The net cash flow in any year t may be defined as

$$a_t = b_t - (k_t + c_t)$$

where b_t are project benefits in year t

k_t are capital outlays in year t

c_t are operating costs in year t .

It is to be noted that when determining these net cash flows, expenditure and income items are included in cash flows at the time when they occur (the time of *transactions*) rather than at the time they are *used*. Thus for example expenditure on purchase of an item of machinery rather than annual allowances for depreciation would enter the cash flows. Similarly, if produce is sold, the timing of the benefit or cash inflow is when payment is received, which is not necessarily when the sale is agreed.

A further point which should be made about cash flows is that they should not include interest payments. The discounting procedure in a sense simulates interest payments, so to include these in the operating costs would be to double-count them. In any case, interest payments within a country represent transfer payments between borrowers and lenders rather than a net cost to society.

Example 1

In order to illustrate the technique of DCF analysis, consider the hypothetical cash flow data of Table 1. Here, a project involves an immediate outlay of \$25,000, with annual expenditures in each of three years of \$4000, and generates revenue in each of three years of \$15,000.

Table 1: Annual cash flows for a hypothetical project

| Year | Project benefits (\$) | Capital outlays (\$) | Operating costs (\$) | Net cash flow (\$) |
|------|-----------------------------|----------------------------|----------------------------|--------------------------|
| 0 | 0 | 25000 | 2000 | -27000 |
| 1 | 15000 | 0 | 4000 | 11000 |
| 2 | 15000 | 0 | 4000 | 11000 |
| 3 | 15000 | 0 | 2000 | 13000 |

Two points may be noted about the way cash flows are set up in Table 1. First, the capital outlay is timed for Year 0. By convention this is the beginning of the first year, i.e. ‘right now’. On the other hand, only half of the first year's operating costs are scheduled for Year 0 (the beginning of the first year). The remaining half of the first year’s operating costs plus the first half of the second year's operating costs are scheduled for Year 1 (the end of the first year or, equivalently, the beginning of the second year). In this way, operating costs are spread equally between the beginning and the end of each year. (The final half of the third year’s operating costs is scheduled for Year 3.) In the case of project benefits, these are assumed to accrue at the end of each year, which would be consistent with lags in production or payments. These within-year timing issues are unlikely to make a great difference to overall project profitability, but it is important to make cash-flow timing assumptions clear.

A second point to note about Table 1 is that net cash flows (second column less third plus fourth column) are at first negative, but then become positive and increase over time. This is a typical pattern of ‘well behaved’ cash flows. For projects with a long life there may be intermittent negative cash flows - for staged investment or replacement of plant and equipment- which can give rise to negative cash flows later on in the life of the project.

4.8 DCF performance criteria

A number of project performance criteria can be obtained by discounted cash flow analysis. These include benefit-to-cost ratios, hence the name of the ‘cost-benefit analysis’ technique. However, in practice other performance criteria are often preferred and B/C ratios are not calculated. The various criteria will now be defined, and derived for the cash flow data of Example 1.

Net present value

The net present value (NPV) is the sum of the discounted annual net cash flows.

$$\text{NPV} = a_0 + a_1/(1+i) + a_2/(1+i)^2 + \dots + a_n/(1+i)^n$$

It is to be noted that a single discount rate i is applied to net cash flows for each year of the project's life. For the above example, taking an interest rate of 8%,

$$\begin{aligned}\text{NPV} &= -27000 + 11000/(1.08) + 11000/(1.08)^2 + 13000/(1.08)^3 \text{ dollars} \\ &= -27000 + 11000/1.1664 + 11000/1.2597 + 13000/1.3605 \text{ dollars} \\ &= -27000 + 10185.19 + 9430.73 + 10319.82 \text{ dollars} \\ &= \$2935.73\end{aligned}$$

A project is regarded as economically viable (i.e. profitable, justified, worthwhile in economic terms) if the NPV is positive. If the NPV is positive, the project can bear the cost of capital (the interest rate) and still leave a benefits surplus. The project of Example 1 can support an 8% interest rate and still generate a surplus of benefits over costs, after allowing for timing differences in these, of approximately \$3000. If the firm or public agency were to proceed with the project, it would end up about \$3000 better off, in terms of today's dollars.

Net future value

An alternative to the net present value is the net future value (NFV), for which annual cash flows are compounded forward to their value at the end of the project's life. This can be derived using the formula

$$\text{NFV} = a_0 (1+i)^n + a_1 (1+i)^{n-1} \dots + a_n$$

Alternatively, the NFV may be obtained indirectly by compounding the NPV forward by the number of years of the project's life. For Example 1, the net future value is

$$\text{NFV} = \text{NPV} (1.08)^3 = \$2935.73 \times 1.2597 = \$3698.18$$

Internal rate of return

The internal rate of return (IRR) is the interest rate such that the discounted sum of net cash flows is zero. If the interest rate were equal to the IRR, the net present value would be exactly zero. The IRR cannot be determined by an algebraic formula, but rather has to be approximated by trial-and-error methods. For Example 1, we know from the NPV calculation that the IRR is somewhere above 8%. In Table 2, a set of trial-and-error discount rates have been used to search for a zero NPV. Starting with an 8% rate, these have been raised in steps of 2%, until at 14% it is found that the cumulative sum is negative (-\$112.10). The IRR must therefore lie between 12% and 14%, but the magnitudes of cumulative present values suggest it is closer to the latter. Rates have been decreased from 14% in steps of 0.1% until a positive cumulative sum (\$27.72) has been obtained at a discount rate of 13.7%. Stepping down from 13.7% in steps of 0.01% yields a cumulative sum of -\$0.34 for a discount rate of 13.76%, which is the approximate IRR.

The above procedure is somewhat imprecise. The order in which changes are made in direction of the interest rate and the sizes of steps will affect how quickly the procedure converges towards the IRR. Greater precision could be obtained by interpolation between interest rates. However, in practice the calculations are normally carried out on computer, so the point of this example is only to illustrate that a trial-and-error process is involved. Calculation of internal rate of return in fact involves solving a polynomial equation, and efficient solution methods such as Newton's approximation are used in computer packages².

² Derivation of the IRR in effect requires solution of the equation

$$a_0 + a_1/(1+i) + a_2/(1+i)^2 + \dots + a_n/(1+i)^n = 0$$

If $1/(1+i)$ is replaced by x , this may be written as

$$a_0 + a_1 x + a_2 x^2 + \dots + a_n x^n = 0$$

which is a polynomial function in the variable x .

Table 2: Sequence of trials in estimation of internal rate of return

| Discount rate (%) | Discounted sum of cash flows (\$) |
|------------------------------|--|
| 8 | 2935.73 |
| 10 | 1858.00 |
| 12 | 843.70 |
| 14 | -112.10 |
| 13.9 | -65.63 |
| 13.8 | -19.02 |
| 13.7 | 27.72 |
| 13.78 | -9.69 |
| 13.76 | -0.34 |

The IRR is a similar measure to percent return on capital, but provides a single summary of the rate of return over the life of the project and is based on present values of costs and benefits. It is an earning rate "internal" to the project, and is the highest interest rate which the project could support and still break even. A project is judged to be worthwhile in economic terms if the internal rate of return is greater than the cost of capital. If this is the case, the project could have supported a higher rate of interest than was actually experienced, and still made a positive payoff. In the above case, the project would be profitable provided the cost of capital were less than 13.76%.

The IRR as a criterion of project profitability suffers from a number of theoretical and practical limitations. On the theoretical side, it assumes that the same rate of return is appropriate when the project is in surplus and when it is in deficit. However, the cost of borrowed funds may be quite different to the earning rate of the firm. It could be more appropriate to use two rates when determining the IRR. The cost of capital could be used when the project is in deficit, and the internal earning rate (unknown, to be determined by trial-and-error) could be applied when the project is in surplus. While a more complex concept, this would give a better indication of the earning rate of the project to the firm or government.

From a practical viewpoint, the IRR may not exist or it may not be unique. This problem can be examined in terms of the *NPV profile* or graph of NPV versus the discount rate. When the IRR is well behaved, this profile takes the form as in Figure 9. In this figure, as the discount rate increases the NPV falls, eventually becoming negative where the NPV curve crosses the

interest rate axis. The discount rate at the point of intersection with the interest rate axis is the internal rate of return.

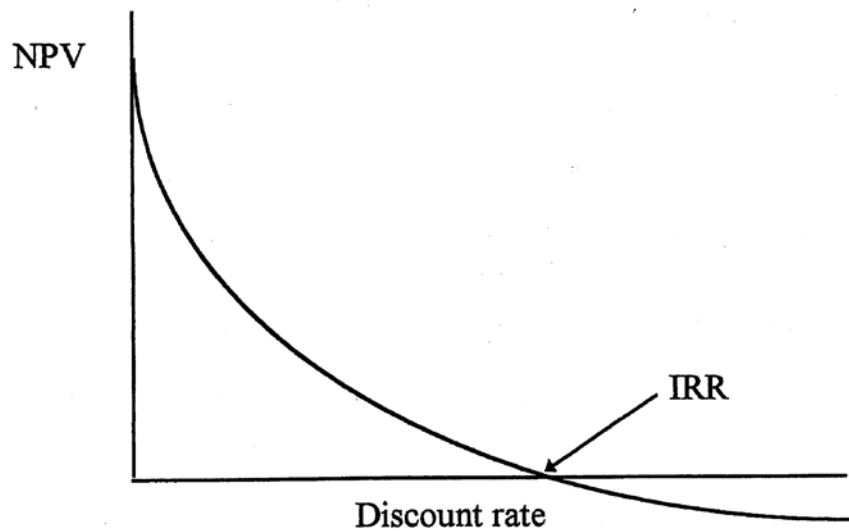


Figure 9 The NPV profile for a project

Now consider a project for which the net cash flow in each year (including Year 0) is positive. Regardless of the discount rate, the NPV will never be zero, so it will not be possible to determine an IRR. Similarly, a project with a large initial capital outlay and for which benefits are relatively small and negative in some years may not have a positive NPV regardless of the interest rate, so again the curve for the NPV profile may always be below the interest rate axis.

If a project generates runs of positive and negative net cash flows, the NPV profile may take the form of a roller-coaster curve, crossing the discount rate axis in several places. This indicates multiple internal rates of return, one at each discount rate where NPV is zero. It is then by no means clear which if any of the rates we should choose to call the IRR. Further, for some sections of the NPV profile (those that are upward sloping), the NPV is increasing as the discount rate increases. This implies that the greater the cost of capital the more profitable the project. Clearly, multiple internal rates of return and perverse relationships between the NPV and discount rate are not very satisfactory³. A project which has alternating runs of positive and negative cash flows is a candidate for problems in estimation of the IRR.

³ As indicated earlier, mathematically the IRR is the solution to a polynomial equation defining the sum of present values of cash flows as a function of the discount rate. This equation can have up to as many 'roots' or solutions as there are turning points in NPV values (changes from positive to negative or negative to positive).

Benefit-to-cost ratios

A number of benefit-to-cost ratio concepts have been developed. For simplicity, only two such concepts will be discussed here, referred to as the gross and net B/C ratios and defined respectively as

$$\begin{aligned}\text{gross B/C ratio} &= \frac{\text{PV of benefits}}{\text{PV of capital costs} + \text{PV of operating costs}} \\ \text{net B/C ratio} &= \frac{\text{PV of benefits} - \text{PV of operating costs}}{\text{PV of capital costs}}\end{aligned}$$

For the project of Example 1, the present value of capital outlays is \$25,000, since outlays are made immediately and as a single amount. The present values of benefits and operating costs are determined as follows:

$$\begin{aligned}\text{PV of benefits} &= \$15000/1.08 + \$15000/1.08^2 + \$15000/1.08^3 \\ &= \$13888.89 + \$12860.08 + \$11907.48 \\ &= \$38656.45\end{aligned}$$

$$\begin{aligned}\text{PV of operating costs} &= \$2000 + \$4000/1.08 + \$4000/1.08^2 + \$2000/1.08^3 \\ &= \$2000 + \$3703.70 + \$3429.36 + \$1587.66 \\ &= \$10720.72\end{aligned}$$

Hence the benefit-to-cost ratios are

$$\begin{aligned}\text{gross B/C ratio} &= \frac{\$38,656.45}{\$25,000 + \$10720.72} = 1.12 \\ \text{net B/C ratio} &= \frac{\$38,656.45 - \$10720.72}{\$25,000} = 1.08\end{aligned}$$

A project is judged to be economically worthwhile if it has a B/C ratio of greater than unity, i.e. if the present value of benefits exceeds the present value of costs (in either gross or net terms). If one of the above ratios is greater than unity, then the other will be greater than unity also. In the above example, the ratios are greater than unity, indicating that the project is

worthwhile on economic grounds. It is not clear on logical grounds which of the ratios are the most useful. Since the net ratio uses capital outlays only in the denominator, it is perhaps a better measure of the return on investment.

If cash flows are divided into more than the three categories of Example 1 (project benefits, capital outlays, operating costs), then it becomes possible to define a greater number of B/C ratio formulae, as is sometimes done. The important point to note is that there is no single or unique definition of a benefit-to-cost ratio.

The payback period

The payback period is the number of years for the projects to break even. That is, it is the number of years for which discounted annual net cash flows must be summed before the sum becomes positive, and remains positive for the rest of the project's life. The payback period for a project with net cash flows of Table can be determined as in the Table 3. The right-hand-side column of this table indicates the project balances, or present values of cumulative net cash amounts committed to the project at the end of each year. The project balances do not become positive until Year 3, so the payback period is three years.

Table 3 Project balances, indicating payback period

| Year | Net cash flow (\$) | PV of net cash flow (\$) | Project balance (cumulative PV of net cash flow) (\$) |
|------|--------------------|--------------------------|---|
| 0 | -27000 | -27000.00 | -27000 |
| 1 | 11000 | 10185.19 | -27000 + 10185.19 = -16814.81 |
| 2 | 11000 | 9430.73 | -16814.81 + 9340.73 = -7384.09 |
| 3 | 13000 | 10319.82 | -7384.09 + 10319.82 = 2935.73 |

In indicating the number of years until the investment in a project is recovered, the payback period is a useful criterion for an agency or firm with a short planning horizon. However, it does not take account of all the information available (in particular the net cash flows for years beyond the payback period) so is not a useful stand-alone criterion.

The peak deficit

This is a measure of the greatest amount that the project 'owes' the firm or government, i.e. the furthestmost 'in the red' the project goes. The peak deficit is the largest negative project balance, which as indicated in Table 3 is -\$27,000. Peak deficit is a useful measure in terms of financing a project, since it indicates the largest amount of finance that will need to be committed to the project, in today's dollars.

4.9 Review of DCF performance criteria

The various criteria defined above are closely related, but measure slightly different things. In this respect, they tend to complement one another, so that it is common to estimate and report more than one of these measures. Perhaps the most useful measure, and the one most often reported, is the net present value. This indicates the total payoff from a project. A limitation of the NPV is that it is not related to the size of the project. If one project has a slightly lower NPV than another, but the capital outlays required are much lower, then the second project will probably be the preferred one. In this sense, a rate of return measure such as the internal rate of return is desirable to supplement the NPV. However, it should be borne in mind that the IRR may not exist, or may not be unique (in which case it is irrelevant).

The net future value does not provide any information additional to that of the NPV if one is positive then the other will be positive also. For this reason, and since decision makers find it easier to think in terms of present-day dollars, the NFV is not usually calculated for projects. The payback period and peak deficit are useful supplementary project information for decision makers. They are particularly important where the agency of firm has a short planning horizon or cannot afford long delays in recouping its expenditure, and where careful attention must be paid to the total amount of funds that will need to be committed to the project. Benefit-to-cost ratios are used mainly in evaluation of large and controversial public sector projects. Like the IRR they provide a rate-of-return figure, but they are not subject to the same computational difficulties as the IRR.

4.10 Summary

This paper commenced by reviewing a number of issues in the use of cost-benefit analysis to animal health programs, providing an overall perspective on application of the technique. Market diagrams have been used to introduce the concepts of producer and consumer surplus, and to provide a conceptual basis for understanding the welfare changes in demand shifts and

access to new markets arising from improvements in animal health. The economic theory presented here should not be viewed as an exact picture of what will happen in the real world. The analysis obviously abstracts from reality in a number of ways, e.g. by assuming a homogeneous product and not allowing for transport costs. However, this kind of presentation does provide a systematic basis for reasoning about how to define or identify the economic impacts of new animal health programs.

The real difficulty of course arises when we attempt to estimate equations for the supply and demand relationships and place money values on changes in producer and consumer surplus. Further, these have to be estimated and aggregated for a number of markets, and for each of a number of years. Even then, we have made only a start on the economic analysis. As well as these impacts (benefits if producer or consumer surplus is increased and costs if it is reduced) allowance must be made for the amounts of public funds invested in the animal health program, changes in marketing costs, impacts on community health, and other factors.

The basic concepts of cost-benefit analysis have been introduced, including the rationale and method of discounting, the concept of a cash flow and the various discounted cash flow performance criteria. The appropriate role of the various criteria has been reviewed.

5. Further reading

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