Invasive Animals Cooperative Research Centre

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Contents

List of tables

List of figures

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Summary

Invasive animal pests have a wide variety of impacts on the economy, the environment and society. There is considerable information on these impacts for individual cases and regions, and McLeod (2004) attempted to value them nationwide for a whole range of pest animals. However, there appear to be no Australia-wide estimates of agricultural losses measured with the economist's concept of welfare and no national or statewide estimates of environmental loss based on the same concept.

In the present report, the direct economic impacts of invasive animals on agriculture in Australia, and the nationwide expenditures by governments and landholders on pest management, administration and research, are estimated. The values of agricultural losses are measured through the concept of economic welfare. The overall impact of pests is calculated here as the sum of the effects on agriculture plus the expenditures on management.

The estimates cover the impact on agriculture of four introduced invasive pest animals, namely: foxes, rabbits, wild dogs and feral pigs. The analysis also includes estimates, taken from literature, of the impact of birds on horticulture and mice on grains.

Method

Economists define an impact as a change in the welfare of consumers and producers, and measure the impact as a change in economic surplus. The welfare or surplus of consumers is the difference between what they are willing to pay and what they have to pay to acquire a good or service. The welfare or surplus of producers is the difference between market price and the cost of production. The economic surplus is the sum of these two individual surpluses.

When invasive animals cause agricultural losses, they reduce welfare. So, the impacts on agriculture should be defined in terms of losses in welfare and measured through losses in economic surplus.

The agricultural loss is measured for a five-year period ending in 2001–02, so 2001–02 is the base year for these values. These losses are estimated separately for foxes, rabbits, wild dogs and feral pigs, and for the main agricultural industries (beef, wool, sheep meat and grains).

Data on the expenditures by governments and landholders on management, administration and research are presented for the year 2007–08.

Impacts on agriculture

The losses in agriculture were estimated from the impact of pests on the marketable quantities of agricultural commodities, and from the abundance and distribution of the pest animals. Losses were estimated as the net annual loss in economic surplus due to the pests.

The annual losses by industry totalled $284.9m:

Industry	$m
Beef	187.7
Wool	71.3
Lamb	20.0
Grains	5.9
Total	**284.9**

Note that the losses in the grain industry are higher than this value of $5.9m per year when there are mouse plagues. McLeod (2004) estimated the yearly cost of these mouse plagues to be $22.8m as the annual equivalent of a plague every 10 years in the mouse-prone regions.

The losses in horticulture were estimated as the losses of production plus the associated management costs. They were adapted from Tracey et al (2007). The annual losses totalled $313.1m, and the losses incurred by industry were:

Industry	**$m**
Wine/grape	120.8
Pome fruit	85.0
Stone fruit	58.4
Nut	48.9
Total	**313.1**

The overall loss in agriculture, including horticulture, is therefore $620.8m (284.9 +22.8 + 313.1). This overall loss can be attributed to the following individual pests:

Pest	**$m**
Birds	313.1
Rabbits	206.0
Wild dogs	48.5
Mice	22.8
Foxes	21.2
Feral Pigs	9.2
Total	**620.8**

Expenditure on management, administration and research

The expenditures on management, administration and research by Commonwealth, state, and territory governments were collected directly from staff of the relevant government agencies for the year 2007-08. The techniques to estimate the impact on agriculture and horticulture already include the costs of control that vary with quantity of pest and quantity of production. The landholders' costs were therefore estimated as the costs of management that are fixed and occur anyway irrespective of the quantity of production. The total Australia-wide expenditures were:

Expenditure by	**$m**
Commonwealth	12.6
States and territories	75.5
Landholders	34.6
Total	**122.7**

The direct economic impact

The direct economic impact comprises the losses in agriculture, including horticulture, and the expenditures on management, administration and research. The nationwide results are:

Economic impact	**$m**
Agriculture	620.8
Expenditures	122.7
Total	**743.5**

We were unable to collect all the data on control costs from all government agencies. Also, estimates of the environmental loss in Australia as a whole are not possible because of lack of data. So, this annual total of $743.5m underestimates the impact of invasive pests in Australia.

Discussion

The estimates of the welfare losses in agriculture are estimated against a no-pest baseline. They are therefore the potential total gains if there were no pests. They cannot be used to determine exactly what should be done or how much should be invested because these decisions need estimates of potential net gains. However, they can be used for the prior (equally important) steps in decision making, namely: raising general awareness, drawing attention to specific issues, demonstrating the size of the problem, defining broad problem areas and formulating broad policies.

Because they are potential total gains, the results assume that the total welfare loss in each industry can be avoided. To explore the possibility that only a portion of these totals can be avoided, a benefit–cost analysis of a range of scenarios concerning investment in research and management to better control pests was undertaken. With a pessimistic scenario that only 2.5% of the losses can be avoided, the benefit–cost ratio of the investment still has a ratio of over 1.0, so the benefits of further research exceed the costs.

Acronyms

ABARE	Australian Bureau of Agriculture and Resource Economics
ABS	Australian Bureau of Statistics
ARIDSEV	Arthur Rylah Institute, Department of Sustainability and Environment, Victoria
BCA	benefit–cost analysis
BCR	benefit–cost ratio
BIOSV	Biosecurity Victoria
BRS	Bureau of Rural Sciences
CMA	Catchment Management Authority
CSIRO	Commonwealth Scientific and Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
DAFWA	Department of Agriculture and Food Western Australia
DECWA	Department of Environment and Conservation Western Australia
DEHSA	Department of Environment and Heritage, South Australia
DEWHA	Department of Environment, Water, Heritage and the Arts
DOCNZ	Department of Conservation, New Zealand
DPIV	Department of Primary Industries, Victoria
DREAM	dynamic research evaluation for management
DSEV	Department of Sustainability and Environment, Victoria
DWLBCSA	Department of Water, Land and Biodiversity Conservation, South Australia
IA CRC	Invasive Animals Cooperative Research Centre
LHPA	Livestock Health and Pest Authority (formerly RLPB: Rural Land Protection Board)
MDBA	Murray–Darling Basin Authority
NPV	net present value
NRM	natural resource management
NRMBSA	Natural Resources Management Board, South Australia
NSWDECC	New South Wales Department of Environment and Climate Change
NSWDPI	New South Wales Department of Primary Industries
NSWNPWS	New South Wales National Parks and Wildlife Service
NTNREAS	Northern Territory Department of Natural Resources, Environment, the Arts and Sport
PCLACT	Parks, Conservation and Lands, Australian Capital Territory
QDEEDI	Queensland Department of Employment, Economic Development and Innovation (incorporates QDPIF: Queensland Department of Primary Industries and Fisheries)
QDPIF	Queensland Department of Primary Industries and Fisheries
QNRMGC	Queensland Natural Resource Management Groups Collective
QERM	Queensland Department of Environment and Resource Management (formerly QNRW: Queensland Natural Resources and Water)
QP&W	Queensland Parks and Wildlife
R&D	research and development
SAAPCG	South Australia Animal Plant Control Group
TDPIW	Tasmania Department of Primary Industries and Water
TFFT	Tasmania Fox Free Taskforce
TP&W	Tasmania Parks and Wildlife
WWF	World Wildlife Fund

1. Introduction

1.1 The invasive animal problem

A great many animals have been introduced into Australia, but most have failed despite the efforts to protect them. For example, 96 species of birds have been introduced, but 52 of these have died out and only a few of the successful introductions have become serious pests (Olsen, 1998). In a national assessment, Bomford and Hart (2002) evaluated the pest status of introduced vertebrate species that now have widespread populations on the mainland. They listed 13 introduced mammals, birds, amphibians and fish as serious pests, 18 as moderate pests, and nine as minor or non-pests.

Invasive pests can cause considerable damage to agriculture and the environment. Wild dogs and foxes kill livestock and poultry, and rabbits compete for pasture. Landholders often cannot run sheep where there is a threat of predation by wild dogs. Camels destroy vegetation, damage fencing and foul waterholes. Wild horses also foul waterholes and can spread weeds. Foxes, feral cats and other pests threaten the survival of many native mammals and birds.

However, some introductions provide benefits as well as costs. Trout are voracious predators of native fish, but are a highly valuable sport fishery. Feral pigs kill lambs and destroy pasture, but can be harvested commercially and also provide a recreational resource for hunters.

These situations create many problems. For example, how can the pest be managed? Should the pest be managed? How much should be invested in management and who should pay for these expenditures? The basic information needed to address these issues is an estimate of the economic costs due to the pest, but first we need to understand what a pest is.

1.2 What is a pest?

In economic terms, an animal is a pest if it decreases welfare, or wellbeing, to the community. The concept of welfare is measured as net benefit, so an animal is a pest if it imposes a net cost on the community. That is, an animal is a pest if the losses it causes exceed the benefits it provides to the community as a whole.

This definition is clearly a net concept that embraces:

- both benefits and costs
- all benefits and costs throughout the community
- benefits and costs in terms of their effects on humans.

These underlying economic principles clearly acknowledge that people decide what a pest is and that an animal is a pest because it conflicts with human interests. This definition covers introduced and native animals and could apply to any natural resource problem, such as introduced plants or salinity.

Where there are no benefits to the community, the decrease in welfare is estimated as a net cost where:

Net cost = Losses in agricultural production + expenditures on control and management by governments and landholders (Equation 1.1)

This net concept closely follows Olsen (1998) and Braysher (1993) who define a pest as an animal that causes more harm than good to a valued resource.

The costs and benefits are difficult to assess because they vary from region to region, they require intensive efforts to collect the necessary values, and because environmental losses are inherently difficult to value. Expenditures continually change, due to factors that influence the status of a pest and the current and expected importance of animals as pests. The significance of a pest also varies with climatic conditions. For example, expenditure on feral pigs and rabbits is presently low due to a combination of the recent drought conditions and the influence of rabbit haemorrhagic disease (RHD). These expenditures, however, will greatly increase when feral pig and rabbit numbers increase as the drought breaks and resistance to RHD virus grows. Similarly, there have been no mouse plagues for several years, but at the time of preparing this report there is a mouse plague on the Darling Downs (Qld) where more than $2m has been spent on mouse bait alone.

The costs and benefits of a particular pest also vary with land use. For example, increases in the cost of irrigation water have encouraged landholders to change from irrigated pasture for dairy and beef cattle to higher-valued crops such as vegetables, rice and grapes. A different set of pests has now emerged and, for example, birds have become a serious and increasing problem. The important pests may also change again if climate change intensifies.

The pest status of an animal can change with time and the perceptions of those affected. Fifteen years ago, feral goats were regarded as a major pest in the rangelands, yet they are now considered a resource by landholders due to an increase in their economic value. Many pastoralists now say that the sale of feral goats has kept them financially viable during the recent drought.

The net costs and the importance of a pest can therefore change over time, between areas, and with the perceptions of people involved.

1.3 Valuation of the costs and benefits

Many studies have attempted to value the costs and benefits of individual pest animals in individual regions. For example, Begg and Davey (1987) estimated that the cost of rabbit control on public lands by the Victorian Department of Conservation and Natural Resources was more than $4m a year. The cost of production losses across Australia from rabbits has been estimated at $115m (Sloane, Cook and King Pty Ltd 1988). Queensland has lost about $33m annually in the form of control costs, livestock losses due to predation by wild dogs, and the diseases that they spread (Rural Management Partners 2004). EconSearch Pty Ltd (2000) carried out a benefit–cost analysis of the wild dog fence and suggested that the cost of maintaining the fence was $1.68m annually.

Invasive animals can be a commercial resource that provides employment and revenue. ACIL (1996) estimated the revenue from the meat and skin industries to be $10m per year and the turnover in sports shooting and ammunition due to rabbits to be $36m. Exports of fox pelts were worth $8m in 1984, although demand has varied widely and prices have fallen in recent years (Saunders et al 1994). Ramsay (1994) reported that export of meat from feral goats to Europe generated $10m to $20m annually.

McLeod (2004) undertook what is perhaps the only comprehensive national study of losses in agriculture and the environment, for a large number of invasive pest species. He estimated the impacts of 12 major introduced pests, namely the European fox, feral cat, rabbit, feral pig, feral dog and dingo, house mouse, carp, feral goat, cane toad, wild horse, camel and kangaroo. The annual impacts on agricultural production were conservatively estimated to be $373.9m, which included both production losses and the costs of control.

These estimates have valued losses in agriculture in several different ways, namely: (i) with gross or net value of losses in income, and (ii) with or without control costs.

However, none of these estimates appear to have been valued with the economist's standard concept of welfare, namely economic surplus.

1.4 Objectives and scope

The goal of this research is to determine the economic impact of invasive animals in Australia, in terms of the agricultural losses that they cause. We apply economic methods to measure the impacts, collect recent data and incorporate indirect and induced costs. All of these steps apply methods based on the principles of welfare economics. The specific objectives of this report are to:

- review the existing economic framework and methods for valuation
- estimate measures of production impacts in agriculture
- estimate expenditures on management and administration.

These outputs are reported in the following chapters. Chapter 2 reviews and introduces the economic framework for valuing impacts on agriculture. The losses in Australian agriculture from invasive pests are then estimated in Chapter 3. Chapter 4 presents the expenditures on management and administration incurred by Commonwealth, state and territory governments, and by farmers. Chapter 5 examines the difference between total and avoidable losses.

The losses to agriculture and the expenditures on control are aggregated in Chapter 6 to indicate the economic impact of selected invasive pests in Australia. Chapter 6 also reviews the strengths and weaknesses of the analysis and the estimates.

The estimation of welfare losses in agriculture, and in production generally, is restricted to four specific major invasive pests, namely: wild dogs, foxes, rabbits and feral pigs. The estimation of production losses, as opposed to welfare losses, is extended to birds in horticulture and to mice. Current consistent national data are available for both these pests. Other animals cause damage and economic losses, but the necessary detailed data for them are unavailable.

1.5 Implications of the results

The results from this research comprise economic estimates of losses in agriculture, and expenditures on management, administration and research. This information will help to demonstrate the importance and the scale of the pest animal problem and the willingness of governments and the community to invest in control. It will help pest animal managers to more completely take account of the costs of invasive pests, and leverage further resources to tackle the problem. More generally, this information will help ensure the most efficient use of limited resources available for the management of pest animals, by allowing targeting of resource allocation.

The estimates of the welfare losses in agriculture are estimated against a no-pest baseline. Therefore, the estimates are the potential total gains if there were no pests. The derived values cannot be used to determine exactly what should be done or how much should be invested, because these decisions need estimates of potential net gains. However, they can be used for the prior (equally important) steps in decision making, namely:

- raising public awareness in general
- drawing attention to specific issues
- demonstrating the size of the problem
- defining broad problem areas
- formulating broad policies.

Because of the complexity of collecting the data, and the variation from year to year and place to place, this kind of economic information has not been provided in the past. Currently, there is a more pressing need for this type of information because of the increased competition for resources.

2. An economic framework for estimating pest losses

2.1 Pests as an economic problem

The impacts of pest animals upon a production system can be illustrated with the basic concept of a production function. The quantity of an agricultural output (eg grain yield, or wool) is determined by the quantity of inputs (fixed or variable) into the production process. The algebraic representation of the production function is:

$$Y = f(V,F) \qquad \text{(Equation 2.1)}$$

where Y is yield, V represents the set of variable production inputs and F represents the fixed production inputs. The variable and fixed production inputs will include factors such as crop variety, livestock type, soil type, soil fertility, rainfall, temperature and diseases. This kind of production function can also be applied to environmental systems, where the output may be the quantity of an environmental amenity or asset. The incidence of pest animals will affect the parameters of this relationship by reducing output for any given level of input. This is illustrated in Figure 2.1 where the production function $f_1(V,F)$ represents the 'pest free' situation and $f_2(V,F)$ represents the 'with pest' situation.

The important argument demonstrated by the production functions is that losses due to pests are not a single number or a constant, but are a relationship where losses are smaller under low input–low output production (*ab*) than under high-input production (*cd*). In the context of this production function, the loss associated with pest animals can be expressed as:

- a reduction in output such as $(Y_0 - Y_1)$ for the low input–low output case, or
- the additional inputs (excluding expenditure on pest control) needed to neutralise the effects of pests $(Y_0 - Y_1)$, or
- any combination of output and revenue adjustments between these extremes.

Introducing input variables specifically for pest animal control (K) extends the production function framework as follows:

$$Y = f(V,K,F) \qquad \text{(Equation 2.2)}$$

Increasing inputs on pest control will reduce the production losses and result in a higher level of output for a given level of other production inputs V and F. This is demonstrated in Figure 2.2 with two production functions, $f(V,K_1,F)$ and $f(V,K_2,F)$, representing increasing levels of pest control input compared to no control inputs for a 'with pests' production function scenario $f(V,F)$. The absolute agricultural output response for a given level of K will depend on the level of input variable V; a greater absolute response will occur at higher levels of V.

Figure 2.1 The effects of pests on a production function

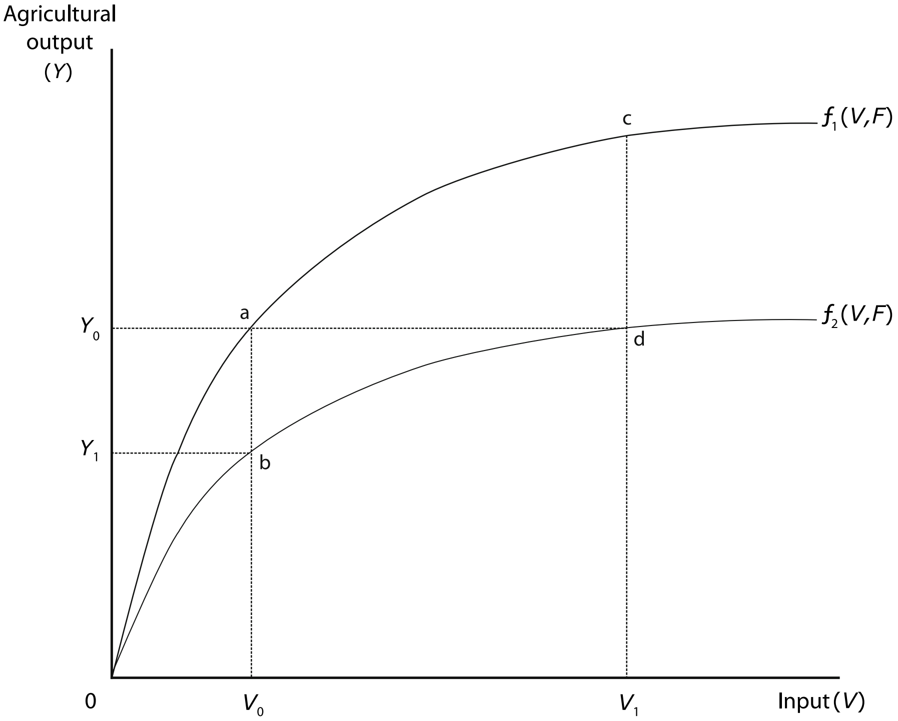
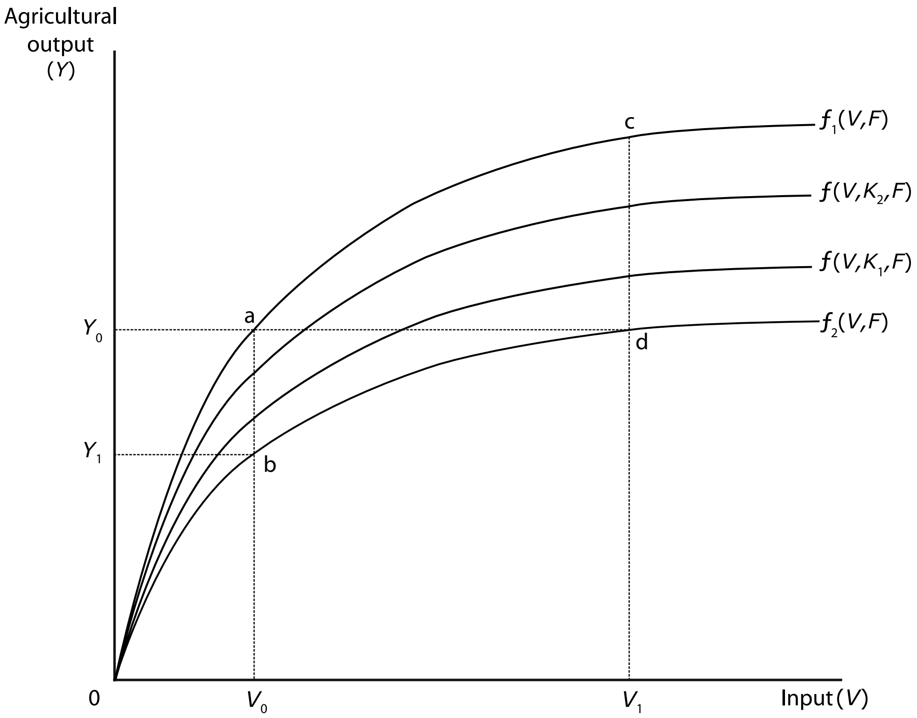


Figure 2.2 The production function with a pest control input



Given that the levels of V, K and F all have an influence on Y, the decision problem faced by a manager is to determine the level of input of all factors of production, including pest control, that maximises net returns. This suggests that there is the potential for an optimal level of pest damage associated with some given level of control. This concept is investigated further in the following section.

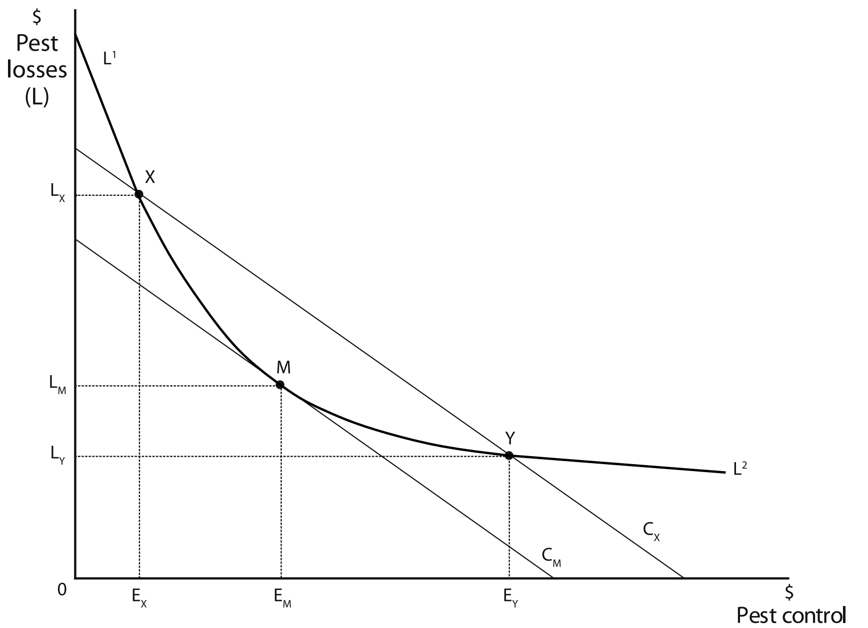
2.2 A loss–expenditure framework

The economic costs associated with a biological problem such as invasive animal impacts comprise the direct losses from predation or competition for resources (L) and the expenditure incurred to control the pest (E). Often, production losses can only be achieved by some increase in control, which leads to an increase in control expenditure. Therefore, there is a tradeoff between minimising production losses and increasing control expenditures.

McInerney (1976, 1996) demonstrated the concept of a loss–expenditure frontier for livestock diseases that applies to the problem of invasive animal impacts. Pest management involves a choice between levels L and E to minimise total cost (C), where C = L+E. These concepts are illustrated in Figure 2.3, where the vertical axis represents the value of pest losses (*L*) and the horizontal axis represents the value of control expenditure (*E*). The locus L^1L^2 represents an efficiency frontier that defines the lowest pest losses attainable for any control expenditure. It illustrates that pest losses can only be reduced by a corresponding increase in pest control expenditure. The relationship between *L* and *E* shows that, in the absence of pest control, losses equal L^1. Losses then decline at a diminishing rate as expenditures on pest control increase, and finally reach some lower asymptote L^2. In this example it is not biologically feasible to eliminate losses. If, on the other hand, the efficiency frontier intersected the horizontal axis then it would be biologically and economically possible to eradicate pests and eliminate losses. Elimination may not result in the lowest possible pest cost because the cost of eradication may be too high.

The isocost lines C_X and C_M indicate the combinations of pest loss and control expenditure that give the same total cost. For example, any combination of *L* and *E* along the *XY* segment of C_X results in the same total cost. The points *X* and *Y* represent two contrasting situations, namely a low pest control and high pest loss scenario (*X*) and a high pest control and low pest loss scenario (*Y*). Moving along the efficiency frontier L^1L^2, by increasing the level of pest control expenditure from *X* towards *Y*, results in lower pest losses and reduces the total pest cost. The lowest pest cost is indicated by point *M*, on the isocost line C_M, which incurs a control expenditure E_M and pest losses of L_M. The equimarginal condition, that the marginal cost from a unit of pest control should equal the marginal benefit from a reduction in pest losses, is satisfied at this point. This means that for every extra dollar in control expenditure a dollar benefit is generated in terms of reduced production losses. Pest losses can be reduced further from point *M*, but the benefits of doing so are negated by the larger additional pest control expenditure required (ie the financial gain is less than the increased expenditure).

Figure 2.3 The loss–expenditure frontier for pest management



Source: McInerney (1996)

This framework is useful because it avoids the comparison of the benefits of a pest control technology to a hypothetical and usually unattainable pest-free scenario. In the context of livestock diseases, McInerney considered that this approach highlighted the irrelevance of estimates of total disease costs because they implied that the points represented by the origin (where no disease costs are incurred) could be attained. It was more relevant to measure the avoidable costs, such as those indicated by $C_X - C_M$. To illustrate this point, assume that a pest control technology results in a shift in pest losses and expenditure from point *X* to point *M* in Figure 2.3. Given that C_M is less than C_X this results in an overall reduction in pest costs. This technological shift can be written as:

$$L_X + E_X > L_M + E_M \text{ , or alternatively}$$
$$L_X - L_M > E_M - E_X \text{ .}$$

This latter expression simply states that the benefits of the technological change in terms of reduced pest losses ($L_X - L_M$) are greater than the additional pest control expenditure ($E_M - E_X$) required to achieve the reduction in losses. It is not worthwhile to reduce pest losses further to point *Y* because the benefits ($L_M - L_Y$) are less than the increase in expenditure required ($E_Y - E_M$). Although the focus is upon measuring the avoidable losses, the estimates of *L* and *E* still require an assessment of the pest-free situation as a base so as to calculate the necessary loss and expenditure values such as L_X and E_X.

The expenditure–loss frontier concept provides a valuable framework for considering the economic impact of pest animals. Specifically, it demonstrates that the total impact of pests is the sum of expenditure on control and production losses. Moreover, it indicates that there is some theoretical minimum cost which involves some positive level of damage from pest animals and some level of pest animal control expenditure. Once information on the damage levels and levels of control expenditure are estimated, the economic impact of a change in the abundance of pest animals can be determined. The concept of a change in economic welfare is appropriate for measuring such impacts. Economic surplus analysis is the framework used here for measuring this welfare change.

2.3 The economic surplus model

The concept of economic surplus is now applied to the problem of measuring the impact of invasive animals upon agricultural production systems. This is achieved by considering various levels of invasive animal abundance from current populations to a theoretical 'without pests' scenario. Then it is possible to consider various 'avoidable cost' scenarios.

2.3.1 The approach

The economic surplus approach considers that pests result in a shift in the supply curve for a particular product such as meat and wool, while the demand curve remains stationary. It is also possible to consider the supply of an environmental amenity as a commodity. The supply of a commodity is reduced from what it otherwise would be due to the effects of predation and competition for resources. This has the effect of raising the cost of producing a given unit of commodity (eg a kilogram of wool). With information about the slopes (elasticities) of the supply and demand for that product, the type of supply shift due to the pest, and the relationship between producer and consumer prices, the impact of a pest animal on a particular industry can be evaluated.

Economic surplus consists of two elements, consumers' surplus and producers' surplus. Consumers' surplus is defined as the extra amount a consumer (buyer) would have been prepared to pay (Currie et al 1971) and is measured by the area below the demand curve and above the price line. The basic premise of consumers' surplus is that at a certain market price there are some consumers who would be willing to pay a higher price in order to obtain the same quantity. These consumers obtain the product at the lower price and so increase their utility. The traditional measure of producers' surplus is the area above the product supply curve and below the price line. This area represents the difference between what a producer (seller) actually receives for a sale and the minimum amount he would have been prepared to accept. Although Mishan (1968) and Currie et al (1971), among others, prefer the term 'economic rent' to 'producers' surplus', the latter term is used here for reasons of convention.

The standard economic surplus model presented by Alston (1991) for measuring the research benefits from a technical innovation is now applied to assess the economic impact of pest animals. This model is similar to the single-process model presented by Lindner and Jarrett (1978) with modification by Rose (1980) and Lindner and Jarrett (1980). We follow McInerney (1996) and measure the current pest losses and pest expenditure in terms of economic values, which we express as a shift in a commodity supply function.

The following simplifying assumptions are made. First, supply and demand curves are linear and any technical innovation would result in a parallel shift in the supply curve. Second, the model is considered as being static. Third, competitive price behaviour applies. Fourth, it is assumed that there are no spillover effects to other countries (Edwards and Freebairn 1982, Davis et al 1987). Finally, it is assumed that the commodities are non-endogenous substitutes, so there are no cross-commodity effects.

2.3.2 The basic model

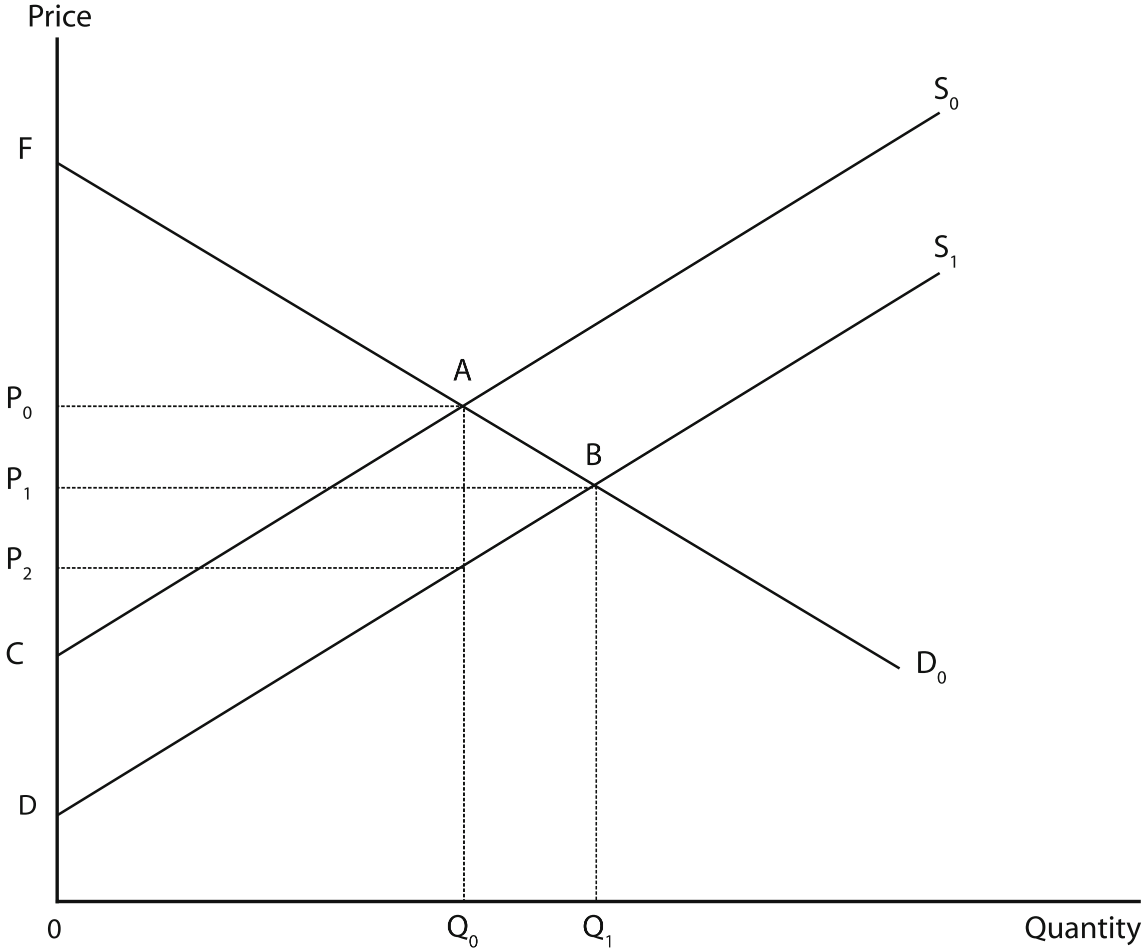
The basic model is illustrated in Figure 2.4. Demand for a homogenous product (eg wool) is represented by the downward sloping demand curve D_0, and S_0 represents the initial supply function. The initial price and quantity equilibriums are P_0 and Q_0. Now consider a technical innovation that reduces the abundance of pest animals within an industry (eg the release of rabbit haemorrhagic disease on the wool industry). The effect of this is to move the supply curve to the right from S_0 to S_1. The output per unit of resource input is increased because the higher levels of pest control reduce the abundance of the pests.

This rightward shift in the supply curve occurs for two reasons. First, expenditure on pest control is reduced or eliminated because there are now fewer pest animals to control. The reduction in the number of pests leads to a reduction in per unit production costs, which is measured as the vertical distance between the supply curves. Consequently, the cost of producing a particular level of output (say Q_0) is lower than prior to the technical innovation. Second, the reduction in pest animals results in a greater level of output (eg wool) with no additional inputs required. Thus, for a given price a higher quantity can be obtained.

Given the current density and abundance of invasive animals, current production of a commodity is represented in Figure 2.4 by Q_0 for which consumers pay a price of P_0. Total economic surplus is represented by the area *FAC*, of which producers have an economic surplus equivalent to P_0AC while consumers' economic surplus is the area P_0AF. The main economic effect of a reduction in invasive animal pests is to reduce per unit production costs and shift the commodity's supply curve outward to S_1, resulting in more output at a lower price. This supply shift is dependent upon the magnitude of the reduction in pest animal abundance. The demand curve D_0 remains stationary because there are no anticipated demand shifts. The area of economic surplus is now *FBD* comprising producers' and consumers' surplus of P_1BD and P_1BF, respectively.

These areas of economic surplus represent the impact of a reduction in pest animal abundance on both consumers and producers. The net change in economic surplus (ΔTS) is measured by the area *CABD*, the difference between the areas *FBD* and *FAC*. This area is the sum of two parts: (i) the cost saving on the original quantity (*CAED*) and (ii) the economic surplus due to the increment to production and consumption (*ABE*). An alternative measure of the net change is to estimate the total benefits in terms of the benefits to consumers from a change in consumer surplus (ΔCS = area P_0ABP_1) and the benefits to producers from a change in producer surplus (ΔPS = area P_1BD – area P_0AC).

Figure 2.4 The basic economic surplus model



Where the supply curves are parallel so that the vertical distance between the two supply curves is constant, and following Alston et al (1995, p210), the changes in the economic surplus areas from a reduction in pest animals can be estimated as:

$$\Delta CS = P_0\, Q_0\, Z(1 + 0.5Z\eta) \qquad \text{(Equation 2.3)}$$

$$\Delta PS = P_0\, Q_0(K - Z)(1 + 0.5Z\eta) \qquad \text{(Equation 2.4)}$$

$$\Delta TS = \Delta CS + \Delta PS = P_0\, Q_0\, K(1 + 0.5Z\eta) \qquad \text{(Equation 2.5)}$$

and $Z = K\varepsilon/(\varepsilon + \eta)$

where P_0 and Q_0 are the initial equilibrium market-clearing price and quantity for the commodity, Z is the reduction in price relative to its initial value due to the supply shift, K is the vertical shift of the supply function expressed as a proportion of the initial price, and ε and η are the price elasticities of supply and demand. With estimates of these parameters the economic surplus equations can then be solved and the change in economic surplus can be estimated.

The K-shift is the proportionate downward shift in the supply curve from S_0 to S_1 at quantity Q_0. It is calculated as the vertical shift (*A-E*), divided by the initial price P_0.

In Figure 2.4, the slopes of the demand and supply curves are approximately equal, so consumers and producers share the total benefits approximately equally (the top and bottom parts of the area P_0ABEP_2 are approximately the same). Consumers benefit from the increase in supply of a commodity (eg wool) that reduces price and the size of the gain depends upon the relative elasticities of supply and demand. The net welfare effect on producers depends on whether the increased industry revenue at the higher production compensates for the price decrease.

2.3.3 The regionally disaggregated model

The economic surplus model illustrated in Figure 2.4 provides a useful theoretical base but has limited applicability because it assumes:

(i) a uniform price reduction across the industry implying a constant effect of pest animals on all producers

(ii) a closed economy without international trade.

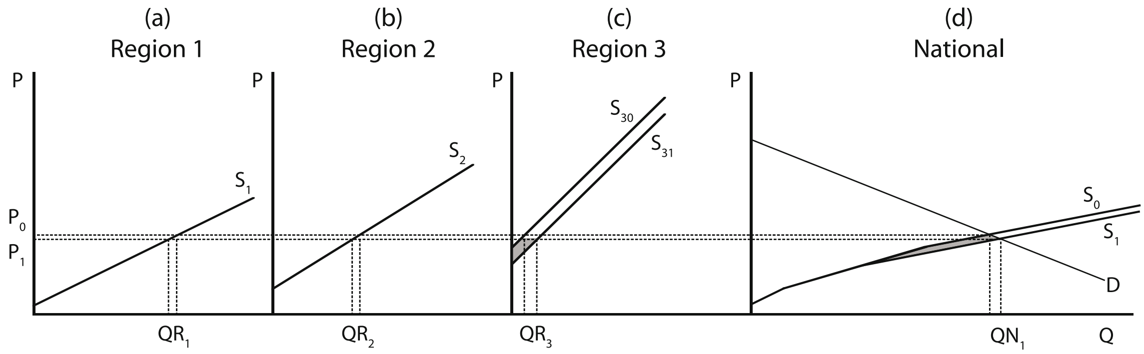
A regionally disaggregated analysis that recognises differences in production environments between regions within an industry would overcome these limitations. For example, the impact of a pest animal such as feral pigs may have a different impact on Queensland production systems compared to Victoria. Thus, any reduction in pig abundance will have differing effects across Australia.

A regionally disaggregated economic surplus model that incorporates international effects of a supply shift due to pest animals is illustrated in Figure 2.5. This model has three production regions that vary sufficiently to have different cost structures (Davis 1994). The different intercepts and slopes of the supply curves indicate the cost variations, and the supply curves aggregate to form the national supply curve. Price is the same in each region but the production levels vary. The three segments of different slope in the national supply curve indicate the three different production levels. Separate regional demands are not considered to be relevant in this example and the national demand determines the prices P_0 and P_1.

In this application of the model, a supply shift due to a pest animal control program in Region 3 increases production in that region but not in the other two regions. The main effect of the supply shift in Region 3 is to reduce price to P_1 in each region because all regions face the same national demand and the price differences $P_0 - P_1$ are the same in each region. Producers in Regions 1 and 2 lose economic surplus because (i) production falls in response to the fall in price to P_1 (ie production declines to QR_1 and QR_2), and (ii) they have not benefited from any program to reduce pest animal impact and thereby reduce their unit costs of production. This differs from Region 3 where the control program lowers average costs and increases production to QR_3. The national effect is the sum of the regional effects, which in this case is an increase in production to QN_1. The national increase in production will be less than that in Region 3 because of the losses to producers in the regions that do not benefit from a reduction in pest animals.

The main points from the framework of Figure 2.5 are that regions have supply curves with different slopes and that the impacts of pest animals can differ between regions thus leading to different supply shifts between regions. This can allow for the inevitable variability in the impact on economic welfare across regions from a reduction in pest animal abundance. Therefore, a regionally disaggregated model is adopted in this study. An advantage of using this model is that by separating an industry into homogenous regions, a different parallel shift can be used in each region to reflect different changes in pest animal abundance and so enable the price spillover effects on other regions to be determined with less error.

Figure 2.5: Regionally disaggregated economic surplus model



Source: Davis (1994)

2.4 Benefit–cost analysis and the returns from research

Estimation of the economic impact of pest animals only represents a partial analysis of the problem. Despite the size of any estimate, important questions still remain such as: (i) can anything be done about the problem, and (ii) should public or private funds be invested to address the issue?

The concept of 'avoidable costs' represents an attempt to focus attention on problems that can be addressed and on policies that provide a net return to society.

New technologies that are developed as an outcome of research can minimise avoidable costs. However, the success of any new technology requires an investment of public and private expenditure on the research itself and adoption of the technology by managers. Estimating the returns from research activities helps to prioritise the allocation of scarce research resources and provides information to assist adoption.

These policy and assessment issues can be addressed through benefit–cost analysis (BCA). The primary objective of BCA is to determine the potential returns on investment from a project involving public expenditure. All the benefits and costs of a project or research program are identified and, where possible, valued. BCA recognises that expenditure on research represents an investment and that the benefits of that investment can be obtained over a number of years. Thus, one of the important features of BCA is the concept of 'discounting'. Whenever the patterns of benefits and costs are distributed over time, discounting is used to convert future cash flows to their present-value monetary amount. The discount rate reflects society's preferences for current and future incomes.

The two main criteria used to estimate returns on investment are the net present value (NPV) and the benefit–cost ratio (BCR). These two criteria are estimated as follows:

$$NPV = \sum_{t=1}^{T} \frac{B_t - C_t}{(1 + r)^t} \qquad \text{(Equation 2.6)}$$

$$BCR = \sum_{t=1}^{T} \frac{B_t}{(1 + r)^t} \Big/ \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t} \qquad \text{(Equation 2.7)}$$

where B_t are benefits in year t, C_t are costs in year t, r is the discount rate, and T is the duration of the proposal. The investment with the highest NPV and BCR is generally preferred, and any project with a negative NPV or a BCR less than unity has a negative return.

2.5 Applying the framework

The economic framework that we have presented, comprises the economic surplus model in its aggregate (Figure 2.4) and regionally disaggregated forms (Figure 2.5). The model rests on the use of production functions (Figures 2.1 and 2.2) to define pests as an economic problem and the loss–expenditure frontier (Figure 2.3) to set the model in a broad policy context. Benefit–cost analysis is the economist's tool to assess the returns to investments, using estimates of economic surplus as the benefit values.

The framework will be applied as follows:

- The regionally disaggregated surplus model will be applied in Chapter 3 to estimate the losses in agricultural production due to invasive pests.
- The loss–expenditure frontier, and its underlying concepts, will be applied in Chapter 4, to guide the collection of data on the expenditures on control, administration and research on invasive pests.

The total of these estimates will be the overall economic impact of pest animals.

3. Estimating the impact on agriculture

The framework of Chapter 2 is now applied to estimate the impact of invasive animal pests on agriculture in Australia. McLeod (2004) calculated the losses of agricultural production for a number of pest animals. The dominant impacts were associated with foxes, feral cats, rabbits, feral pigs, wild dogs and mice. This identification of the more significant pests is supported by the literature and follows the information we collected while defining the present problem. So, we have concentrated on rabbits, foxes, wild dogs and feral pigs, and estimated their impact on agriculture as a loss in economic surplus. We estimate the impact of birds and mice as a loss in yield and increase in costs of control, because these impacts on horticultural and grains industries respectively have been well documented.

We have omitted feral cats from the calculations of economic surplus, but have included them in the assessment of control expenditures in Chapter 4. McLeod (2004) identified only minor economic impacts for other species such as feral goats, camels, cane toads and horses, so these have been excluded from the present study. The economic impact of feral pigs on the beef industry has also been excluded because it appears to be relatively small.

3.1 Impacts on the livestock and cropping industries

The regionally disaggregated economic surplus model was now applied to measure the impacts of invasive animals on each of the main agricultural industries in Australia, namely beef, wool, sheep-meat and grains. In this process, each industry was disaggregated into a number of production, consumption and international trading regions.

3.1.1 The estimation of changes in economic surplus

The changes in economic surplus were calculated with the DREAM (dynamic research evaluation for management) model developed by Wood et al (2001). This model is based on the economic principles for research evaluation that are detailed in Alston et al (1995). DREAM has been refined and used by the major agricultural research funding agencies in Australia and throughout the world. The model has a rigorous theoretical base and requires a specific set of parameter values, including equilibrium prices and quantities, supply and demand elasticities, and commodity supply shifts.

We apply the horizontally disaggregated, multiregion option in the DREAM model. This option can evaluate the impact of a cost increasing entity, such as an invasive pest, where the product is relatively freely traded across a number of regions (Alston et al 1995). It captures the multiregional and international trade status of the particular agricultural industries of interest. The main disadvantage is that the potential impact on the vertical market segments of the industry, such as processors and retailers, cannot be assessed. The estimated impact therefore relates to the farm level as the point of exchange and the price, quantity and elasticity values chosen reflect this part of the relevant industries.

The DREAM model operates in an equilibrium displacement context; that is, the equilibrium is displaced from point A with the pest in Figure 2.4 to point B without it. So, the model uses equilibrium values for the input prices and quantities to define the size and structure of the market in each region. It also uses elasticities of supply and demand to predict how producers and consumers in each region will react to new prices generated by the simulated shocks to the market from the impact of pest animals.

3.1.2 The collection of market data

The market data to apply the DREAM model for each industry are given in Tables 3.1 to 3.4. They were obtained from a variety of sources, including Australian Bureau of Agriculture and Resource Economics (ABARE) Commodity Statistics and various international databases.

The beef industry was specified in terms of eight Australian producing regions and four international trading regions. The Australian regions were: Queensland, New South Wales, Victoria, Tasmania, South Australia, Northern Territory, Western Australia – north, and Western Australia – south. The international regions were: Japan, Korea, United States, and the rest of the world. The DREAM model has been used in extensive evaluations of beef industry technologies and in the estimation of potential national benefits of the Beef Cooperative Research Centre.

Table 3.1: Market data for the beef industry

Region	Price ($/t)	Price links	Production quantity (kt)	Consumption quantity (kt)	Supply elasticity (ε)	Demand elasticity (η)
NSW	3130	0.80	475	296	1.00	-0.33
Qld	2634	0.80	1007	129	0.75	-0.27
Vic	3223	0.80	363	171	1.00	-0.33
Tas	2773	0.80	45	17	1.00	-0.33
SA	2714	0.80	91	54	1.00	-0.33
WA south	2550	0.80	50	50	1.00	-0.33
WA north	2550	0.50	111	18	0.75	-0.27
NT	0592	0.50	51	7	0.75	-0.27
Japan	5110	0.70	457	1207	0.70	-2.00
Korea	4295	0.70	190	580	0.70	-2.00
United States	4016	0.80	11762	12268	1.00	-3.00
Rest of world	4016	0.50	35753	35556	1.00	-5.00

The wool industry was disaggregated into five Australian regions and five international trading regions. The Australian regions were New South Wales, Queensland, Victoria, South Australia and Western Australia. The international regions were the European Union, New Zealand, United States, China, and the rest of the world. The DREAM model has been applied to evaluate technologies developed by the Sheep Cooperative Research Centre.

Table 3.2: Market data for the wool industry

Region	Price ($/t)	Price links	Production quantity (kt)	Consumption quantity (kt)	Supply elasticity (ε)	Demand elasticity (η)
NSW	6500	0.80	232	3	0.80	-0.50
Qld	6500	0.80	52	3	0.50	-0.50
Vic	6500	0.80	123	3	0.50	-0.50
SA	6500	0.80	82	3	0.50	-0.50
WA	6500	0.80	147	3	0.50	-0.50
European Union	6500	0.80	177	346	0.50	-0.24
New Zealand	6500	0.80	256	23	0.33	-0.47
United States	6500	0.80	22	44	0.50	-0.50
China	6500	0.80	281	329	0.80	-0.59
Rest of world	6500	0.80	912	1527	0.80	-0.35

The sheep-meat industry was disaggregated into five Australian regions and five international trading regions. The Australian regions were New South Wales, Queensland, Victoria, South Australia and Western Australia. The international regions were the European Union, New Zealand, United States, China, and the rest of the world.

Table 3.3: Market data for the sheep-meat industry

Region	Price ($/t)	Price links	Production quantity (kt)	Consumption quantity (kt)	Supply elasticity (ε)	Demand elasticity (η)
NSW	3489	0.80	90	58	1.38	-0.66
Qld	3489	0.80	19	12	1.38	-0.66
Vic	3489	0.80	142	90	1.38	-0.66
SA	3489	0.80	45	21	1.38	-0.66
WA	3489	0.80	46	29	1.38	-0.66
European Union	3489	0.80	826	1105	0.67	-0.92
New Zealand	3489	0.80	422	46	0.50	-0.25
United States	3489	0.80	108	138	0.50	-0.50
China	3489	0.80	1339	1425	0.30	-0.19
Rest of world	3489	0.80	2073	2186	0.50	-0.26

The grains industry represents an aggregation of the main Australian winter crops (wheat, oats, barley, triticale, canola, and grain legumes) and summer crops (sorghum). The Australian regions were each state (with the exception of Tasmania and Northern Territory) and there was an aggregate rest of world trading region. The DREAM model was applied to measure weed losses to the Australian winter cropping region (Jones et al 2000, Sinden et al 2004) and has been used to measure the potential return from investment in a proposed Invasive Plants Cooperative Research Centre (Jones et al 2006).

Table 3.4: Market data for the grains industry

Region	Price ($/t)	Price links	Production quantity (kt)	Consumption quantity (kt)	Supply elasticity (ε)	Demand elasticity (η)
NSW	232	0.80	9984	4041	0.36	-2.20
Qld	232	0.80	1755	375	0.36	-2.20
Vic	232	0.80	3863	1533	0.36	-2.20
SA	232	0.80	5546	1899	0.36	-2.20
WA	232	0.80	11617	1575	0.36	-2.20
Rest of world	232	0.80	827388	850734	0.50	-5.00

3.1.3 The collection of data on supply shifts

The potential shift in supply, from eliminating the impact of pest animals, was derived for each individual combination of industry, state and pest animal. The K-shifts for each of these individual combinations were derived from (i) estimates of the biological impact of each pest on production in each industry, and (ii) estimates of the abundance of each pest in each state. The weighted average industry K-shift was determined by the aggregation of these two estimates. The abundance levels had been reported as low, medium and high, so the K-shifts were determined on the same basis.

We therefore followed these steps to calculate the required K values:

(i) The biological impacts of each pest animal on agricultural production were identified from previous studies and reported in Table 3.5. The main impact of wild dogs is to increase the mortality rates of both juvenile and adult stock due to predation (Fleming et al 2001). However, the effect of predation by foxes (Saunders and McLeod 2007) and feral pigs (Choquenot et al 1996) is largely confined to juvenile stock. According to Croft et al (2002), Fleming et al (2002) and Williams et al (1995, pp 61–64), the main impact of rabbits is to reduce the sale weight of calves and lambs, and reduce the amount of wool produced per animal.

(ii) Gross margin budgets were obtained from the New South Wales Department of Primary Industries (NSWDPI) (http://www.dpi.nsw.gov.au/) for each agricultural industry. The biological changes, from Table 3.5, were incorporated into each of these budgets to calculate the changes in the cost of producing a unit of each commodity. The approach followed the recommendation of Alston et al (1995, p330) by adjusting for changes in input mixes that would occur with any change in pest animal abundance. The budgets were then used to calculate individual K-shifts by industry for scenarios of low, medium and high pest abundance (Table 3.6).

(iii) The distribution or abundance of each pest for each industry was estimated at a state level (Table 3.7), from the pest distribution maps developed by NSWDPI (West and Saunders 2003, 2007). The values for each abundance or industry scenario were then subjected to a peer review process involving a group of pest animal researchers (Glen Saunders, Peter Fleming and Peter West, 2007, personal communication).

(iv) The aggregate K-shift values were obtained by multiplying the values in Table 3.6 by the values in Table 3.7. The resulting values for each industry/state/pest animal scenario are shown Table 3.8. These aggregate values were then incorporated into the DREAM model for each industry to represent the supply shift if the effect of pest animals were removed.

Table 3.5: Production impact of pest animals at low, medium and high densities (%)

	Low density	Medium density	High density
Wild dogs			
(a) on adult stock:			
beef industry	1	2	5
wool industry	1	3	10
sheep-meat industry	1	3	10
(b) on juvenile stock:			
beef industry	1	3	10
wool industry	1	3	10
sheep-meat industry	1	3	10
Foxes			
beef industry	0	0	0
wool industry	1	2	5
sheep-meat industry	1	2	5
Rabbits			
beef industry	2.3	4.3	13.7
wool industry	0	4.3	15.0
sheep-meat industry	2.3	4.3	13.7
Pigs			
beef industry	0	0	0
wool industry	4	7	9
sheep-meat industry	4	7	9
grains industry	1	2	3

Table 3.6: Estimated K-shifts for by industry and pest animal for low, medium and high densities (%)

Industry	Wild dogs/ dingoes	Foxes	Rabbits	Feral pigs
Lamb industry				
low density	1.16	0.54	1.64	2.10
medium density	3.47	1.07	3.07	3.40
high density	11.83	2.57	9.79	4.30
Wool industry				
low density	1.14	0.54	0.00	0.97
medium density	3.40	1.07	2.90	2.00
high density	12.55	2.57	6.40	2.50
Beef industry				
low density	0.75	0.00	3.63	0.00
medium density	3.00	0.00	6.69	0.00
high density	7.33	0.00	19.80	0.00
Grains industry				
low density	0.00	0.00	0.00	0.99
medium density	0.00	0.00	0.00	1.96
high density	0.00	0.00	0.00	2.91

Table 3.7: Distribution of pest density across industry by state (%)

	QLD	NSW	VIC	SA	WA	NT
Wild dogs						
Beef industry:						
zero density	80	90	95	95	80	80
low density	5	5	5	5	5	5
medium density	10	5	0	0	10	10
high density	5	0	0	0	5	5
Wool industry:						
zero density	80	90	95	85	80	100
low density	5	5	5	10	8	0
medium density	10	5	0	5	10	0
high density	5	0	0	0	2	0
Sheep-meat industry:						
zero density	90	90	98	0	98	100
low density	10	5	2	0	2	0
medium density	0	5	0	0	0	0
high density	0	0	0	0	0	0
Foxes						
Beef industry:						
zero density	100	100	100	100	100	100
low density	0	0	0	0	0	0
medium density	0	0	0	0	0	0
high density	0	0	0	0	0	0
Wool industry:						
zero density	60	60	60	60	60	100
low density	15	10	15	15	15	0
medium density	20	20	20	20	20	0
high density	5	10	5	5	5	0
Sheep-meat industry:						
zero density	60	60	60	60	70	100
low density	15	15	20	20	15	0
medium density	20	15	15	15	15	0
high density	5	10	5	5	0	0
Rabbits						
Beef industry:						
zero density	60	70	70	60	60	100
low density	10	5	5	10	10	0
medium density	20	10	10	20	20	0
high density	10	5	5	10	10	0
Wool industry:						
zero density	60	70	70	60	60	100
low density	10	5	5	10	10	0
medium density	20	10	10	20	20	0
high density	10	5	5	10	10	0
Sheep-meat industry:						
zero density	60	70	70	60	60	100
low density	10	5	5	10	10	0
medium density	20	10	10	20	20	0
high density	10	5	5	10	10	0

	QLD	NSW	VIC	SA	WA	NT
Feral pigs						
Beef industry:						
zero density	100	100	100	100	100	100
low density	0	0	0	0	0	0
medium density	0	0	0	0	0	0
high density	0	0	0	0	0	0
Wool industry:						
zero density	95	90	100	100	100	100
low density	2	4	0	0	0	0
medium density	3	5	0	0	0	0
high density	0	1	0	0	0	0
Sheep-meat industry:						
zero density	95	90	100	100	100	100
low density	2	4	0	0	0	0
medium density	3	5	0	0	0	0
high density	0	1	0	0	0	0
Grains industry:						
zero density	90	85	100	100	100	100
low density	4	10	0	0	0	0
medium density	3	3	0	0	0	0
high density	3	2	0	0	0	0

Table 3.8: Estimated K-shifts for each industry by state (%)

	QLD	NSW	VIC	SA	WA	NT
Wild dogs						
lamb industry	0.12	0.23	0.02	0.00	0.02	0.00
wool industry	0.85	0.85	0.06	0.28	0.68	0.00
beef industry	0.74	0.19	0.04	0.04	0.70	0.70
Foxes						
lamb industry	0.42	0.50	0.40	0.40	0.24	0.00
wool industry	0.42	0.53	0.42	0.42	0.42	0.00
Rabbits						
lamb industry	1.76	0.88	0.88	1.76	1.76	0.00
wool industry	1.22	0.61	0.61	1.22	1.22	0.00
beef industry	3.68	1.84	1.84	3.68	3.68	0.00
Feral pigs						
lamb industry	0.14	0.30	0.00	0.00	0.00	0.00
wool industry	0.08	0.16	0.00	0.00	0.00	0.00
grains industry	0.19	0.22	0.00	0.00	0.00	0.00

3.1.4 The loss of economic surplus due to pests

The results of the economic surplus analysis for each industry and pest animal scenario are reported in Tables 3.9 to 3.13. The results are the changes in surplus between the 'with' and 'without' pest animal scenarios, which give a measure of the maximum economic gain that could be achieved if pests were eradicated from these industries.

The analysis indicates that if the combined impact of dogs, foxes, rabbits and pigs were removed from the beef, sheep and grains industries, then the total economic surplus would be improved by some $284.87m per annum (Table 3.9). The results for the change in producer and consumer surplus show that producers will receive the majority of the benefit ($282.73m), compared to consumers ($2.14m). The beef industry would incur the greatest benefit ($187.73m) from a reduction in invasive animals, followed by the wool industry ($71.28m) and the lamb industry ($20.00m). These industry changes reflect the relative size of the different agricultural sectors.

Table 3.10 shows the associated results for the economic impact of pest animals in Australia on welfare in Australia and the rest of the world, taken together. The results exhibit similar magnitudes and rankings of the importance of the different industries.

The impacts are summarised by pest (Tables 3.11 and 3.12) and by industry/pest/state in Table 3.13. Rabbits impose the greatest loss in economic surplus ($206.01m), followed by wild dogs ($48.53m) and foxes ($21.15m). The impact of feral pigs is relatively minor ($9.19m).

The impacts are disaggregated by industry/pest/state in Table 3.13. These impacts indicate that annual losses:

- by industry/pest are highest for rabbits and beef ($161.05m)
- by pest/state are highest for rabbits in Queensland ($98.30m)
- by state are highest for Queensland ($128.06m) and New South Wales ($69.61m)
- in the rest of the world are, naturally, small ($13.2m).

These results, of course, reflect the data that have been applied to the model, which themselves reflect the relative sizes of the agricultural industries in each state.

Table 3.9: Annual loss in economic surplus to Australia only due to selected pest animals ($m)

Industry affected	Consumer surplus	Producer surplus	Economic surplus
Beef industry			
by wild dogs	0.09	26.59	26.68
by rabbits	0.54	160.51	161.05
Subtotal	0.62	187.10	187.73
Lamb industry			
by wild dogs	0.06	0.85	0.90
by rabbits	0.84	12.59	13.43
by foxes	0.29	4.38	4.67
by feral pigs	0.06	0.94	1.00
Subtotal	1.25	18.75	20.00
Wool industry			
by wild dogs	0.08	20.87	20.95
by rabbits	0.12	31.42	31.54
by foxes	0.06	16.42	16.48
by feral pigs	0.01	2.31	2.32
Subtotal	0.27	71.01	71.28
Grains industry			
by feral pigs	0.00	5.86	5.86
Total	**2.14**	**282.73**	**284.87**

Table 3.10: Annual loss in economic surplus to Australia and other countries due to selected pest animals ($m)

Industry affected	Consumer surplus	Producer surplus	Economic surplus
Beef industry			
by wild dogs	5.92	20.93	26.85
by rabbits	36.42	125.70	162.11
Subtotal	42.34	146.63	188.97
Lamb industry			
by wild dogs	1.37	-0.44	0.94
by rabbits	20.33	-6.37	13.96
by foxes	7.11	-2.25	4.85
by feral pigs	1.53	-0.48	1.04
Subtotal	30.33	-9.55	20.79
Wool industry			
by wild dogs	11.96	12.25	24.20
by rabbits	17.99	18.44	36.44
by foxes	9.41	9.63	19.04
by feral pigs	1.33	1.36	2.68
Subtotal	40.69	41.68	82.36
Grains industry			
by feral pigs	0.39	5.49	5.87
Total	**113.74**	**184.24**	**297.99**

Table 3.11: Annual loss in consumer surplus, producer surplus and total economic surplus to Australia only due to wild dogs, rabbits, foxes and feral pigs ($m)

Pest	Consumer surplus	Producer surplus	Economic surplus
Wild dogs	0.22	48.30	48.53
Rabbits	1.49	204.52	206.01
Foxes	0.35	20.79	21.15
Feral pigs	0.08	9.11	9.19
Total	**2.14**	**282.73**	**284.87**

Table 3.12: Annual loss in consumer surplus, producer surplus and total economic surplus to Australia and other countries due to wild dogs, rabbits, foxes and feral pigs ($m)

Pest	Consumer surplus	Producer surplus	Economic surplus
Wild dogs	19.25	32.74	51.99
Rabbits	74.74	137.77	212.51
Foxes	16.52	7.38	23.89
Feral pigs	3.24	6.36	9.60
Total	**113.74**	**184.24**	**297.99**

Table 3.13: Annual economic surplus losses by pest animal upon beef, lamb wool and grains industries ($m)[1]

	Beef industry		Lamb industry			
	Wild dogs	**Rabbits**	**Wild dogs**	**Foxes**	**Rabbits**	**Feral pigs**
Qld	19.58	98.30	0.08	0.27	1.14	0.09
NSW	2.81	27.47	0.72	1.54	2.66	0.94
Vic/Tas	0.44	21.56	0.09	1.91	4.17	-0.02
SA	0.09	9.23	-0.01	0.59	2.68	-0.01
WA	2.84	4.52	0.03	0.36	2.77	0.00
NT	0.92	-0.03				
Australia	26.68	161.05	0.90	4.67	13.43	1.00
Rest of world	0.17	1.06	0.04	0.18	0.53	0.04
Total	**26.85**	**162.50**	**0.94**	**4.85**	**13.96**	**1.04**

	Wool industry				Grains	Total
	Wild dogs	**Foxes**	**Rabbits**	**Feral pigs**	**Feral pigs**	
Qld	2.62	1.22	3.75	0.24	0.77	128.06
NSW	11.64	7.06	7.40	2.28	5.10	69.61
Vic/Tas	-0.15	2.87	3.94	-0.07	0.00	34.73
SA	1.08	1.91	5.90	-0.05	0.00	21.42
WA	5.75	3.42	10.55	-0.08	0.00	30.15
NT						0.89
Australia	20.95	16.48	31.54	2.32	5.86	284.87
Rest of world	3.26	2.56	4.90	0.36	0.01	13.12
Total	**24.20**	**19.04**	**36.44**	**2.68**	**5.87**	**297.99**

[1] The results in the table are annual losses due to pests, measured in terms of changes in economic surplus. The negative results therefore indicate annual gains. These gains occur when output in an industry in one area increases, through the market forces, to balance losses in the same industry in another area. All the negative numbers are small.

3.2 Impacts of birds on horticulture

3.2.1 The nature of the information

Tracey et al (2007) surveyed a nationwide sample of horticultural growers, and reported considerable losses of production due to bird pests. The survey was conducted between 2003 and 2005 (Tracey, personal communication, 2007; Tracey et al 2007), and collected information from 1,582 growers across all Australian states and across the main horticultural industries. The main damage from birds appeared to be in the wine and grape, pome fruit, stone fruit, and nut industries. We now review and summarise these yield losses and estimate the associated expenditure on control costs.

The yield losses arise from damage to shoots, stems, foliage, buds and fruits, and secondary spoilage through infection with moulds, yeasts, bacteria and insect damage. Losses will of course vary across regions, industries and seasons (Halse 1990, Subramanya 1994, Komdeur et al 2005). The main control methods for reducing this damage are netting (drape-over or permanent), acoustic deterrents, visual deterrents (kites and balloons), shooting and chemicals.

Each of the control methods involves initial establishment and annual maintenance costs. The initial cost of control is a one-off investment, which Tracey et al (2007) converted to its annual equivalent for the life expectation of each of the different methods. The annual costs were set at the control costs of the previous year. Tracey et al (2007) derived the average expenditures per farm and per hectare in this way.

3.2.2 The value of the losses

The value of the production losses for each of four horticultural industries was calculated from the average percentage loss in each and the total value of production in each (Tracey et al 2007). Based on the national survey, Tracey (personal communication, 2007) estimated the average production losses to be 7% for wine and table grapes, 13% for apples and pears, 16% for stone fruits, and 22% for nuts. The total value of production across each industry was taken from Australian Bureau of Statistics (ABS) data for 2005–06. They then calculated the values of the production loss for each industry as:

$$\text{Production loss} = \text{percentage loss of production} \times \text{total value of production} \quad \text{(Equation 3.1)}$$

The value of the production losses were estimated to be \$48.9m for nuts, \$83.7m for pome fruit, \$55.1m for stone fruit and \$102.2 for wine and grapes, to give a total of \$289.9m. These losses are listed in Table 3.14.

We estimate the expenditures on control costs as follows. The average cost of control per hectare was identified for each horticultural industry from the national survey, and the total number of hectares in each industry was obtained from ABS data. The total expenditure on control in an industry was then calculated as:

$$\text{Expenditure on control} = \text{average cost per hectare} \times \text{total number of hectares} \quad \text{(Equation 3.2)}$$

For example, the total cost of control for the wine/grape industry was \$10.37m over a total harvested area of 94,112 hectares in the survey sample, so the average control cost was \$110.2 per hectare. According to ABS statistics, the total planting area for the wine industry was 168,790 hectares in 2006. Therefore, the nationwide total cost of control for the wine industry was calculated as (\$110.2 × 168,790), to give \$18.6m. The control expenditures for pome fruit and stone fruit industries were calculated in the same way and the results are included in Table 3.14. There were insufficient data to estimate these costs for the nut industry.

Table 3.14: Annual economic impact of bird damage (\$m)

Industry	**Losses**	**Expenditure**	**Total cost**
Nuts	48.9	na	48.9
Pome fruit	83.7	1.3	85.0
Stone fruit	55.1	3.3	58.4
Wine/grapes	102.2	18.6	120.8
Total	**289.9**	**23.2**	**313.1**

The estimated total annual impact of bird pests on horticulture is therefore \$313.1m. As Table 3.14 shows, yield losses comprise most of this total. The nut, pome fruit, stone fruit, and wine/grape industries all bear considerable bird damage, as do other industries for which data are unavailable.

3.3 Impacts of mice on agriculture

Mice do most of their damage to crops, but can also cause losses in poultry and piggery enterprises. They regularly damage farm equipment, machinery, vehicles, household items, building insulation and the personal possessions of farm households. Caughley et al (1994) estimated that the economic loss in the 1993 mouse plague was $61m in Victoria and South Australia. McLeod (2004) estimated a production loss of $22.8m as the annual equivalent of a mouse plague every 10 years in each of the mouse-prone production regions. Data are not available for other individual mouse plagues, so we apply McLeod's 2004 estimate.

3.4 The overall impacts on agriculture

The total annual losses in each agricultural industry are summarised in Table 3.15. They comprise the economic surplus estimates of net losses for foxes, rabbits, wild dogs and feral pigs from Table 3.9, the loss from birds in horticulture from Table 3.14, and the estimate for mice from Section 3.3. The overall impact of these pest animals is $620.8m.

The results of the Table 3.15 suggest that:

- many agricultural and horticultural industries bear serious losses from pests
- in agriculture, the beef industry bears the highest loss
- in horticulture, the wine and grape industry bears the highest loss.

Table 3.15: Overall annual impacts on agricultural and horticultural industries ($m)

Industry	Pest			Total
	Foxes, rabbits, wild dogs, feral pigs[1]	Birds[2]	Mice[2]	
Beef	187.7			187.7
Lamb	20.0			20.0
Wool	71.3			71.3
Grains	5.9		22.8	28.7
Nuts		48.9		48.9
Pome fruit		85.0		85.0
Stone fruit		58.4		58.4
Wine /grapes		120.8		120.8
Totals	**284.9**	**313.1**	**22.8**	**620.8**

[1] These are estimates of net losses as the change in economic surplus.
[2] These are estimates of total losses as the change in gross revenue.

All these estimates are annual losses. The agricultural results refer to the five-year period ending in 2001–02, so 2001–02 is the base year for these values. The horticultural results were compiled with data for the period 2003–06. Estimation at other times would inevitably lead to different results.

4. Estimating expenditures on management, administration, and research

4.1 The context

The economic costs associated with a biological problem, such as pest animals, comprise the direct losses (L) and the expenditures (E) incurred in management, administration, and research. Following Section 2.2, the total economic costs (C) are calculated as:

$$C = L + E \qquad \text{(Equation 4.1)}$$

The economic losses (L) in agriculture were estimated in Chapter 3. So we now turn to the expenditures (E) on management, administration and research. If there were no damage from pest animals there would be no such expenditures, so these outlays are part of the total economic costs of the pests.

Both government agencies and private landholders undertake pest management. Government agencies formulate policy, undertake research, develop and administer programs, provide information, enforce legislative requirements and directly manage pests. The different levels of government, including the Commonwealth, state and territory governments, regional resource management bodies, special management agencies and local authorities, are all involved.

Governments influence activities on agricultural land in many ways, and operate directly in the public conservation estate, state forests, defence lands, other crown land. Landholders are responsible for the management of pests on their land although they consult the relevant government agencies for technical advice and assistance with coordinated planning and implementation of large-scale pest management programs.

We need, therefore, to collect data on government and landholder expenditures but we recognise that such data can only represent the situation at a given time. The expenditures and importance of a pest can change over time, between areas, and with the perceptions of those involved.

4.2 Purpose and method

The purpose of this chapter is therefore to estimate the expenditure on management, administration and research related to major invasive animal pests. The level of these expenditures can only be a snapshot at a given time, and perhaps only an incomplete snapshot. Nevertheless, the level will demonstrate the community's concern about the damage that pest animals cause to agriculture and the conservation estate.

We contacted many people in government departments and agencies, non-government organisations and landholders to elicit data for the financial year 2007–08. After reviewing earlier attempts to collect this kind of expenditure, we adopted several guidelines to lend consistency to this process.

- We report results at relatively high levels of aggregation. For example, we have avoided trying to detail an agency's expenditures by function such as field management, administration and research. This level of disaggregation encourages inconsistencies because of the difficulty in eliciting information on separate functions. Therefore we report the more reliable aggregate figures per department and agency.

- We attempt to report total expenditures by an agency or organisation from all its funding sources. For example, a state agency may be undertaking a substantial management program supported by both state and Commonwealth funding. In this case, all expenditure is attributed to the agency because that organisation is undertaking the program. To avoid double-counting, the outside funds are then omitted from the expenditures of the outside funding bodies.
- We include the cost of volunteer labour, where it has been valued consistently at an hourly rate. Volunteer time is part of the total resources devoted by society to pest management, and is often a large or crucial input.
- We omit the environmental, emotional and community costs that accompany pest invasions. They can be significant, and so will be covered in separate reports for the Invasive Animals Cooperative Research Centre (IA CRC). Some farmers describe losses of stock to wild dogs like being robbed day after day, and relate the emotional drain on their lives from the sight of dead and mutilated sheep. The cost is not only emotional, but can significantly affect the productivity of daily farm management.

The expenditures by Commonwealth, state and territory agencies are reported next in Section 4.3, followed by estimates of landholder costs in Section 4.4. The available data by pest are summarised in Section 4.5, and Section 4.6 presents the final discussion.

4.3 Expenditures by Commonwealth, state and territory governments

We now turn to the expenditures by the Commonwealth, state and territory governments, and include a brief statement of the administrative arrangements in each of these jurisdictions.

4.3.1 The Commonwealth

The Department of Environment, Water, Heritage and the Arts (DEWHA) provides extensive funds for pest animal research and management on the conservation estate throughout Australia. In addition they manage pest animals on their own estate, which includes Kakadu, Uluru and Booderie National Parks and Christmas and Norfolk Islands.

The Bureau of Rural Sciences (BRS) within the Department of Agriculture, Fisheries and Forestry (DAFF), supports research into the management of production damage due to pests.

The Department of Defence is a major landholder. The department undertakes extensive pest animal management to protect defence uses on their lands and as part of a cooperative pest management program with their neighbours.

The direct expenditures by the Commonwealth in 2007–08 are summarised in Table 4.1. The IA CRC invests $4.367m on average each year for research projects and its PhD program. The Murray–Darling Basin Authority (MDBA) spends a total of $0.600m a year on research and management, mainly on carp and their treatment. This does not include the $1.1m that the MDBA provides to the IA CRC for the daughterless carp program, which has been incorporated into the IA CRC expenditure. The BRS reports investment of $0.740m in research projects.

DEWHA funded projects worth $2.430m in 2006–07, not including the Fox Eradication Scheme in Tasmania. Expenditure on pest management by Parks Australia totalled $4.5m, of which $4m was specified funding for Crazy Ant control on Christmas Island. The expenditure covered Uluru–Kata Tjuta, Booderee, Christmas Island and Norfolk Island National Parks. This figure includes staff time, and the expenditure and focus on pests can vary significantly depending on the conditions.

Table 4.1: Expenditures by the Commonwealth for the year 2007–08 ($m)

Agency	Total
IA CRC	4.367
MDBA	0.600
BRS, DAFF	0.740
DEWHA	2.430
Commonwealth Conservation Estate	4.5
Total	**12.637**

The Commonwealth Scientific and Research Organisation (CSIRO) Sustainable Ecosystems division has significant annual expenditure on pest research but no accurate figures are available. The total expenditure by Commonwealth agencies is therefore estimated to be at least $12.637m.

4.3.2 The states and territories

There are several classes of land in the states, including private land, vacant crown land, leased crown land, and the conservation estate. Each state and territory has its own arrangements for managing pest animals on these lands. The major agencies are, typically, a department of primary industries, a department of the environment, and the natural resource management (NRM) bodies. In some states, NRM bodies are largely independent of government. In others, such as South Australia, previous pest management agencies have been incorporated into the NRM boards. The expenditures for each state and territory are summarised in Table 4.2.

New South Wales

The primary agency for setting pest management policy is the Pest Animal Council for New South Wales. The Council comprises representatives of the major land management agencies, including the NSWDPI, New South Wales Department of Environment and Climate Change (NSWDECC), NSW Forests (within NSWDPI), Livestock Health and Pest Authorities (LHPAs), and the New South Wales Farmers Association.

The NSWDPI is responsible for policy and research on agricultural land, other production land and vacant crown land. NSW Forests is responsible for state forest lands, and the New South Wales National Parks and Wildlife Service (NSWNPWS, within NSWDECC) has responsibility for the conservation estate.

The 14 LHPAs receive funds through landholder levies and undertake significant amounts of onground management. The 13 Catchment Management Authorities (CMAs: the NRM bodies in New South Wales) also undertake pest animal management within their region.

The NSWDPI spent $8.042m on pest management in 2007–08, of which the LHPAs outlaid $4.988m and NSW Forests spent $0.540m. The NSWNPWS spent $10.250m on the conservation lands and the CMAs outlaid a further $2.6m on pest management.

Queensland

Biosecurity Queensland, within the Queensland Department of Primary Industries and Fisheries (QDPIF*), is the main body responsible for pest animal policy, research and management in Queensland. Regional Land Protection Officers coordinate research and management, on pests and weeds, with local government and NRM bodies.

The total research expenditure by Biosecurity Queensland, for both production and the conservation impact of pests, was $1.479m in 2007–08. The annual cost of maintaining the

* The Queensland Department of Primary Industries and Fisheries (QDPIF) is now a division of the Queensland Department of Employment, Economic Development and Innovation (QDEEDI).

Wild Dog Barrier Fence was $0.770m. Thus, the total expenditure by the QDPIF within the Queensland Department of Employment, Economic Development and Innovation (QDEEDI) is set at the total of these two costs, namely $2.249m. Queensland Parks and Wildlife expend some $2.300m a year on managing pest animals, and the regional NRM bodies spent a further $2.811m in pest animal management in 2007–2008. This was achieved through funding from National Action Plan for Salinity and Water Quality, Natural Heritage Trust phase 2 and National Landcare Program. Except for the costs of maintaining the Wild Dog Barrier Fence, expenditures by the NRM bodies were not collected so these expenditures are not included in Table 4.2.

South Australia

The major agency responsible for policy and research direction on both production and crown land is the Animal and Plant Control Group, which is part of the Department of Water, Land and Biodiversity Conservation, South Australia (DWLBCSA). The Department of Environment and Heritage South Australia (DEHSA) is the land manager for the state reserve system and crown estate and so is responsible for managing pest animals on these lands. As an environmental agency, the DEHSA also contributes to broad scale off-reserve management programs in conjunction with other state, corporate and private land managers. SA Water and Forestry SA are responsible for management in their particular jurisdictions.

Table 4.2: Expenditures by state and territory governments for the year 2007–08 ($m)

Department	NSW	Qld	SA	Tas	Vic	WA	ACT	NT
Primary industry	8.042	2.249	0.871	4.980	7.990	6.400		
Environment	10.250	2.300	1.745	3.540	5.392	8.089	0.660	0.011
NRM Bodies	2.600	2.811	6.482					
Other agencies			1.078					

The DWLBCSA invested $0.871m on pest research and management in 2007–08 and the DEHSA expenditure was at least $1.745m. The NRM regional bodies play a major role as field managers in South Australia. Their expenditure of $6.482m in 2007–08 includes external funds such as those provided to them by non-government organisations. The annual cost of maintaining the Wild Dog Barrier Fence in South Australia, $0.770m, was included in the 'Other agencies' category along with expenditures by SA Water and Forestry SA.

The DWLBCSA costs of $0.871m include $0.721m for research and $0.150m for policy, technical support, and compliance. The research includes some investigations undertaken by the DEHSA. This department spent a further $0.265m to develop, manage and implement pest management policies on the conservation estate. We have omitted the volunteer labour involvement in pest animal management as well as the costs of the DEHSA scheme of grants to pest animal management. The figures for South Australia therefore underestimate the state expenditure on pest animal management.

Tasmania

The main authority for setting policy, research directions, and coordinating and conducting onground pest management is the Tasmanian Department of Primary Industries and Water (TDPIW). The Biosecurity and Integrity Division (of TDPIW) manage pests on public land and provide advice to private landholders. A separate group, the TDPIW Fox Eradication Branch is responsible for the fox eradication program. Tasmania Parks and Wildlife undertakes pest research and management on the conservation estate and conducts the rodent and rabbit program on Macquarie Island. Forestry Tasmania manages pests on forest lands, although expenditure is mainly to manage the damage due to browsing by native mammals.

The Fox Eradication Branch comprises 34 field staff plus scientific and administrative support. The program has a budget of $56m over ten years and $4.980m was spent in 2007–08.

The budget for the program to eradicate rabbits and other pests from Macquarie Island is $24.7m for the period from 2007–08 to 2016–17. The program is funded equally by Tasmania and the Commonwealth with $0.1m from the World Wildlife Fund (WWF) and Peregrine Adventures. The annual expenditure, from both sources, is approximately $3.54m.

Victoria

Biosecurity Victoria has overall responsibility for pest management on all lands, and the specific responsibility for developing a biosecurity approach for weeds and pest animals. This agency is a division of the Department of Primary Industries, Victoria (DPIV) and liaises closely with the Department of Sustainability and Environment, Victoria (DSEV).

Farm Services Victoria, a division of DPIV, is responsible for service delivery on private land, and the Biosciences Research division of DPIV undertakes weeds research to meet policy objectives. The DSEV is responsible for pest management on public land and conducts pest animal research on behalf of Biosecurity Victoria. DSEV also has responsibilities on state forest and unreserved crown land, and its division, Parks Victoria, is responsible for the management of pest animals on the conservation estate.

The CMAs are responsible for planning through the development of action plans, and for advising on regional pest management priorities.

In 2007–08, the DPIV budget for these purposes totalled $7.990m. The budget for the DSEV totalled $5.392m, of which $3.400m was allocated to Parks Victoria.

Western Australia

The Department of Agriculture and Food Western Australia (DAFWA) sets policy and research priorities, and assists the Department of Environment and Conservation Western Australia (DECWA) in the coordination and management of pest animals on crown land. DAFWA works closely within the regulatory framework, and provides technical advice to private landholders to manage pests on their land. Previously, Zone Control Authorities coordinated pest management in the regions, but these are being progressively replaced by Regional Biosecurity Groups. The DECWA has primary responsibility for policy, research and management of the conservation estate. It also has responsibility for onground management of non-metropolitan non-town site Unallocated Crown Land and Unmanaged Reserves, for the control of declared animals on an area of approximately 89 million hectares, and for the management of pest animals on vast tracts of unallocated crown land.

The primary focus of the state’s NRM groups is on conservation management, revegetation, salinity and erosion. They work independently of DAFWA with respect to biosecurity and pest management. However they cooperate where they have obtained state funds and where they involve the local community in pest and weed management programs. DAFWA delivers operational services to NRM groups implementing pest management programs.

The Biosecurity and Agricultural Management Act 2007 promotes the formation of industry funding schemes for any industry or group of industries. For example, the objective of a scheme for the cattle and sheep industry might be to eradicate/contain/manage a pest. The costs are estimated and the Management Committee asks the Minister to impose a mandatory charge on the industry to finance the scheme. DAFWA provides support to ensure proper operation and governance of the schemes.

Expenditure by DAFWA on research, policy, regulation and technical advice was approximately $6.400m in 2007–08. DECWA spent $8.089m on managing pest animals. Landholders spent further substantial sums, but these are covered in Section 4.4.

Australian Capital Territory

The primary agency for setting policy, undertaking research, and conducting pest management in the Australian Capital Territory is the Division of Parks, Conservation and Lands (PCLACT) within the Department of Transport and Municipal Services. The PCLACT conducts pest management on the land that they manage, advises and assists on private leasehold land, and undertakes pest animal research.

In 2007–08, the PCLACT incurred an expenditure of $0.660m on the operating, labour and research costs of pest management. There is also significant annual expenditure on wild dog management through cooperative programs with stock producers on adjoining New South Wales lands.

Northern Territory

The major agency responsible for policy and research on both production and crown land is the Natural Resources Management Division of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport (NTNREAS). The Parks Division of the Department is responsible for managing pest animals as a land manager of the territory reserve system, while Parks Australia (DEWHA) manages pests within Uluru–Kata Tjuta and Kakadu National Parks.

The Natural Resources Management Division provides integrated support, advice, monitoring and regulatory services in regard to the territory's natural resources. This includes relevant research on the biology, damage and management of major animal pests. As well as pest management on the crown estate, the division works cooperatively with many indigenous ranger groups on Indigenous Protected Areas, and with pastoralists and NRM bodies to help coordinate and manage the damage due to pests.

Major recent initiatives include an upgrade of the emergency response programs to ensure preparedness for any exotic disease incursion (developed with relevant state, Commonwealth and other Northern Territory agencies), collaboration with the Northern Territory Cattleman's Association to develop mechanisms to manage wild dogs, programs to manage pest animals on Indigenous Protected Areas, and the preparation of a major report on the biology, damage and management of feral camels. Accurate data are not available on the costs of management and research associated with pest animals in the Northern Territory. But as an example, the Natural Resources Management Division spent approximately $0.011m on wild dog management (based on data from Eldridge et al 2002, converted to 2008 values).

4.3.3 The results

In the financial year 2007–08, the overall expenditure by the Commonwealth was $12.637m (Table 4.1), and expenditure by states and territories totalled $75.490m (Table 4.2). The expenditures are listed in four categories for each jurisdiction in Table 4.2. But the total expenditure by jurisdiction is more relevant than these individual categories because:

- pest management expenditures may vary by category more due to the particular administrative arrangements than to any characteristic of the pests
- aggregate data may be more reliable than its individual components for this kind of information.

So for the present purposes, these overall expenditures are the principal result from this review of government outlays.

4.4 Expenditures by landholders

4.4.1 The required information

Invasive pests significantly increase the costs of agricultural production, and expenditure on pest management is one of these costs, as discussed in Chapter 2 and modelled in Figure 2.4. There is a vertical downward shift in supply from S_0 in the initial situation with pests to S_1 with a reduced abundance of pests. The loss due to pests in agriculture is therefore calculated as the net change in economic surplus (area *CABD* in Figure 2.4), which is a loss of net benefits.

This shift in supply models the changes in production cost, and incorporates the changes in expenditure on pest management that vary directly with the level of production. So the area *CABD* nets out these changes in variable expenditures. However, this measure does not net out the expenditures that are fixed and occur at all levels of production so that the landholder can:

- monitor the occurrence of the pests
- maintain a lower level of pests at S_1
- meet the administrative requirements of pest management.

We now estimate these extra fixed costs that the landholder incurs due to pest animals.

4.4.2 Procedure and data collection

A systematic procedure to derive this information is to obtain a national estimate of the average cost per farm and to multiply this average by the number of farms.

Total landholder expenditure = average cost per farm × number of farms

(Equation 4.2)

The numbers of livestock farms are taken from the ABARE data base for 2005–06, and the numbers of grain farms are taken from ABS (2005, document 7123.6.55.001). The livestock farms comprise beef, sheep and lamb producers. The beef category includes both specialist beef farms and mixed-enterprise beef farms. A sheep producer is any broadacre farmer with more than 200 head of sheep and a lamb producer is anyone who sells more then 100 lambs in the year. A grain farmer is any landholder with an annual value of cropping operations of $5000 or more. The number of farms in these categories is summarised by state and territory in Table 4.3.

The average costs per farm were more difficult to collect. The ABS (2008) has recently surveyed landholders about natural resource management issues on their farms. The bureau set out to identify the type and extent of weed, pest, land, and soil problems, to identify the activities that farmers undertook to address the problems, and to estimate their costs in doing so.

The bureau estimated that expenditure on pest management totalled $768m during 2006–07 over all 150,403 farms in Australia. The average total cost is therefore $5100 per farm. Of this total, 56.0% was spent on pesticides, 10.0% on contractor labour, 19.9% on other hired labour and 14.1% (or $109m) on other items. The first three categories are expenditures that vary directly with the quantity of the pests and quantity of output. The fourth class (the 'other items') comprises all other costs and so will include the remaining costs that vary with the quantity of production as well as the fixed costs. So the maximum value per farm for the fixed costs that occur anyway is the average 'other cost', which is $725 per farm ($109m/150,403 farms).

The ABS costs cover four groups of pests, namely: native animals and birds, feral and domestic animals, insects, and others. The value of $725 per farm will therefore be an overestimate for the present purposes because it covers pests other than invasive animal pests. The value of $725 per farm is therefore a maximum for the required fixed costs.

Bomford and Hart (2002) assumed that the average Australian farm spent a total of $250 per year to manage pests and repair pest damage. This sum includes the fixed costs of management.

The following broadscale evidence was collected during the present study:

- In Queensland, the total landholder expenditure was estimated to be $8.4m for 2007–08 (Andrew Drysdale, personal communication, 2008), which is $625 per farm.
- In Western Australia in 2007–08, farmers spent a total of $6m on management of pests, which is about $420 per farm.
- In New South Wales, the main damage from feral goats is fence maintenance and competition for water. The estimate of these costs for the 70 farms involved is about $250 for each property.

The average property size in the ABS (2008) survey was 2830 ha. So in a practical sense $250 per property would likely just meet the current annual vehicle costs of monitoring a farm of this size for the occurrence of pests.

On the basis of these estimates, the maximum value of the fixed costs per property is judged to be $400 per farm, the minimum is $250, and a conservative $325 per farm is adopted as the preferred estimate.

4.4.3 The results

These data on farm numbers and cost per farm are now applied to Equation (4.2) and the results for a cost of $325 are shown in Table 4.3 for all states and territories. The total landholder expenditure, in $m per year for each of the three cost levels, now follows.

Minimum ($250)	$26.606 m
Preferred ($325)	**$34.588 m**
Maximum ($400)	$42.570 m

We use the preferred figure of $34.588m.

Table 4.3: Expenditures by landholders: at $325 per farm

State or territory	Number of farms			Expenditure ($m)
	Livestock	Grain	Total	
NSW	34,082	3,164	37,246	12.105
Qld	12,027	1,417	13,444	4.369[1]
SA	12,254	3,143	15,397	5.004
Tas	2,068	0	2,068	0.672
Vic	21,599	2,069	23,668	7.692
WA	12,133	2,289	14,422	4.687
NT	180	0	180	0.059
Total			**106,425**	**34.558**

4.5 Expenditure by pest animal

4.5.1 The available data

Data on the expenditures by individual pests were available for New South Wales, South Australia, Victoria, Western Australia and the Australian Capital Territory. They are one measure of the relative importance of the different pests in each jurisdiction, given the current climate, land uses and available government funds. The data are reported in Table 4.4 as total expenditures for the year 2007–08 per pest.

The information for New South Wales refers specifically to the National Parks and Wildlife Service. The South Australian data covers expenditure by all departments, NRM boards and other government agencies. The information for Victoria includes the DPIV, Parks Victoria, and other expenditures by DSEV. The data for Western Australia covers separately (i) agricultural production through private landholders, local government, NRM regional groups and volunteers, and (ii) the conservation estate managed by DECWA. The information for the Australian Capital Territory concerns expenditures by the PCLACT for operating, labour, and research costs.

The total expenditures of Table 4.4 match those of Table 4.2 when all expenditures for the state or the department could be allocated to individual pests. For example, the expenditures match for Victoria ($13.382m), the conservation estate in Western Australia ($8.089m), and the Australian Capital Territory ($0.660m). But the total expenditure for the NSWNPWS is $10.250m in Table 4.2 and $4.188m in Table 4.4, because the latter is confined to direct management and operational expenditures plus the Fox Threat Abatement Planning. The total for South Australia is $10.176m in Table 4.2 and $5.801m in Table 4.4 because the latter omits the expenditure by the departments and the NRM bodies where there was no breakdown by pest. The total for Western Australia for agricultural production is $10.399m in Table 4.4 and $6.400m for DAFWA in Table 4.2. The expenditure in Table 4.4 is higher because it includes landholder costs.

4.5.2 The results

The general observations on the results of Table 4.4 are that many pests are being managed and substantial funds are applied to each.

The more specific observations may be listed as follows:

- In New South Wales, wild dogs and foxes attract the highest NSWNPWS expenditures per pest.
- In South Australia, wild dogs, foxes and rabbits have the highest expenditures per pest.
- In Victoria, wild dogs, foxes, and rabbits all involve high expenditures.
- In Western Australia, birds and wild dogs incur the highest expenditures in agricultural production.
- In Western Australia, foxes, feral cats and cane toads create the greatest expenditures per pest on the conservation estate.

Table 4.4: Allocation of expenditures by pest, for the year 2007–08 ($m)

Pest	NSW	SA	VIC	WA		ACT
	conservation estate	all	all	agriculture	conservation estate	all
Wild dogs	1.410	1.161	4.235	1.980	0.450	0.181
Foxes	1.270[1]	1.106	2.384	0.990	2.200	0.025
Feral pigs	0.530	0.091	0.188	0.990	0.185	0.212
Feral goats	0.330	0.656		0.999	0.100	0.002
Rabbits	0.018	1.058	4.835	0.770		0.192
Feral cats	0.140	0.075		0.660	1.650[2]	
Birds		0.087		2.800	0.275	
Camels		0.135		0.330	0.040	
Donkeys		0.010		0.330	0.135	
Horses		0.010		0.110		0.046
Cane toads		0.015			0.876	
Deer		0.386				
Other	0.490	1.011	1.740	0.440	2.178[3]	0.003
Total	**4.188**	**5.801**	**13.382**	**10.399**	**8.089**	**0.660**

[1] The $1.270m for foxes in the NSWNPWS comprises expenditure for direct management and for Fox Threat Abatement Planning.

[2] The $1.650m for the feral cats in WA conservation estate comprises expenditure on direct management and on one year of the cat mesopredator work.

[3] The 'other' category for the WA conservation estate includes expenditure on pest cattle, protection fencing, and its own 'other' category.

4.6 Discussion

These estimates of expenditures on management, administration and research for 2007–08 may be summarised as follows:

Expenditure by	$m
Commonwealth	12.637
States and territories	75.490
Landholders	34.558
Total	**122.685**

By way of comparison, McLeod (2004) also estimated the expenditures on management and research on invasive pests in Australia. His expenditure data were basically the landholder costs of pest management plus the research costs from Bomford and Hart (2002), for the eight invasive pests of foxes, rabbits, dogs, pigs, goats, mice, horses and feral cats. His total expenditure for these pests was $88m. In the earlier review of agricultural losses, damage costs and management expenditures, Bomford and Hart (2002) had estimated that (i) landholders and governments in Australia spend more than $60m per year controlling introduced vertebrate pests and (ii) Australian governments spent another $20m a year on research to manage these pests.

There are limitations to the present estimate of $122.685m for the expenditures on management, administration, and research in 2007–08:

- Little data were available on local government costs, and training costs.
- Staff often undertake tasks with several outputs, only one of which is concerned with pest management. But the staff costs cannot be allocated by outputs.
- Consistent data on volunteer labour were only available for two states.
- The landholder costs are the fixed costs of monitoring and maintaining lower levels of infestation.

While there remain gaps in the data, there appears to be no further consistent information available at the time of writing.

These results are therefore minimum estimates of the expenditures. Nevertheless, they clearly indicate that pest management is a significant issue of natural resource management, and a large amount of resources are invested in management, administration and research by the Commonwealth, all states and territories, as well as landholders.

5. Estimating the potential returns from research

5.1 Introduction

The elimination of all the costs imposed by invasive animal pests may not be feasible, or economically desirable. In any case, the relevant cost to assess investments and choices is the 'avoidable cost', a concept that was introduced in Chapter 2. This represents the part of the problem that something can be done about so it is the economically relevant part (McInerney 1996).

There are two ways to ameliorate the economic losses due to invasive animals. First, a greater reduction in losses can perhaps be achieved by increasing expenditure on control. This implies that the current level of control is suboptimal with the current stock of knowledge and technologies. Second, scientific research may develop new technology that reduces losses for the same level of expenditure. The economic objective is to achieve an increase in agricultural productivity or environmental goods where more output can be produced with the same amount of inputs, or the same amount of output can be produced with fewer inputs (Alston et al 1995).

The impact of a research induced technology change upon a commodity was illustrated in Figure 2.4 in terms of a change in economic surplus. This is a conventional, comparative–static, partial equilibrium model of supply and demand in a commodity market. As previously described in Chapter 2, a shift in the supply function from S_0 to S_1 due to the new technology (eg a biological control agent) results in new equilibrium prices and quantities and a gross annual research benefit represented by the area *CABD*. This use of economic surplus models, through the inclusion of shift in the supply curve from S_0 to S_1 (the *K*-shift), allows us to estimate the change in economic surplus (*CABD*) and the distributional impacts upon producers and consumers.

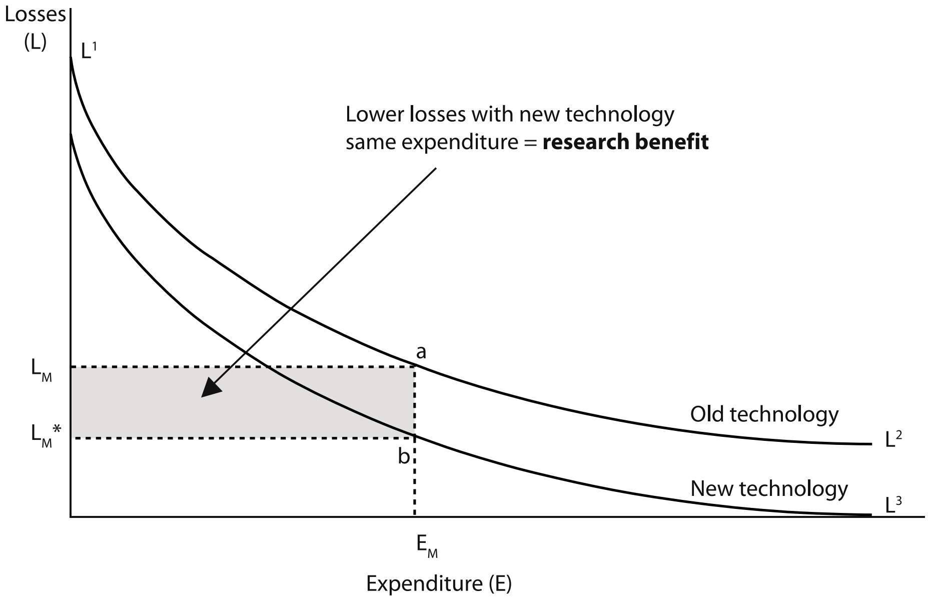
Another way to represent the impact of a new technology is through the loss–expenditure framework of Figure 2.3, which is now adapted to Figure 5.1. The original loss–expenditure frontier is L_1L_2. The introduction of a new technology shifts this frontier down to L_1L_3, which is equivalent to the shift in the supply function of Figure 2.4. In Figure 5.1 the new loss–expenditure frontier shows that for the same amount of expenditure on control (E_M) a lower level of losses from invasive animals occurs (L_M^*). The area $L_M abL_M^*$ represents the benefit from the new technology.

The objective of a national research organisation, such as the IA CRC, is to develop knowledge and technologies to improve agricultural productivity and protect environmental assets. The benefits from such research can be estimated using economic surplus techniques. But there are additional issues pertaining to the time lags in realising the research benefits and the costs relating to the research process and adopting the new technologies.

It is useful to distinguish between the research and development (R&D) lag, where the technology is under development, and the adoption lag that follows. Adoption usually commences once the R&D phase is complete, and increases over time until some maximum level is reached. The longer the total lag period (R&D and adoption) the lower will be the overall benefit of research because the benefits occur further into the future. The practice of discounting future monetary benefits to a present value reflects these differential valuations of benefits over time.

The research process is not costless and there are likely to be substantial expenditures during the R&D phase. Once the adoption phase commences there are likely to be additional costs involved in achieving adoption. These may include various promotions, government extension activities and workshops. The actual costs of using a new technology (eg adoption of new pest control by farmers) are usually incorporated into the cost of producing a commodity and will be accounted for in the estimate of the K-shift.

Figure 5.1 The effect of a new technology on the loss–expenditure frontier



5.2 Objectives and method

Objectives

The results from Chapters 3 and 4 comprise estimates of the total costs of pests on agriculture and management expenditures. They are useful indicators of the total costs of invasive pests in the economy. But the policy issues concern (i) whether more or less control is desirable, and (ii) whether particular investments are economically worthwhile.

We will therefore apply results we have obtained so far to estimate the potential returns from research and control for invasive pest animals. More specifically, the objective of the present chapter is to apply the estimates of the losses in agriculture, and supporting information, to estimate the economic desirability of investment in research to develop new technology to reduce the costs of invasive animals. In doing so, we specifically introduce information on the difference between total costs and avoidable costs and introduce the adoption lags.

Method

The method is to use scenario analysis to estimate the potential net returns from research into developing new knowledge and technology to ameliorate the costs of invasive animals in Australia. This analysis does not attempt to measure the benefits from an individual research project or research agency such as the IA CRC. Such a study would necessarily involve the constructions of ‘with-CRC’ and ‘without-CRC’ scenarios, which is beyond the scope of this analysis (but see Jones et al 2006). Consequently, we address the broader research question of what is the potential aggregate return from investment in research that results in a reduction in the losses associated with invasive animals, regardless of who carries out the research.

The benefit from the research is the cost that is avoided. There are considerable uncertainties surrounding the size of this benefit, the lag in achieving it, and the costs of research, development and adoption. Consequently, the analysis elicits a range of benefit–cost ratios (BCRs) and net present values (NPVs) for various assumptions about the benefit, costs and lags. The results are presented in a factorial table format (Tables 5.1 and 5.2). Thus, even though there is uncertainty surrounding the basic inputs, this analysis provides knowledge as to the potential return for various input combinations.

Data

The annual benefits are calculated from the total annual losses to agriculture from invasive animals, which was taken as $598m. This is the loss from foxes, rabbits, wild dogs and feral pigs ($284.9m), the loss from mice ($22.8), and the yield loss in horticulture ($289.9m), from Tables 3.14 and 3.15. It omits the control expenditures in horticulture ($23.2m) because these seem to be the least avoidable of all the losses. The avoidable cost was assumed to range from 2.5% to 15.0% of this total loss of $598m so the potential annual benefits range from $15.0m (2.5% of $598m) to $89.7m (15% of $598m).

A constant R&D lag of six years is assumed, however the adoption lag ranges from 5 to 20 years. This gives a range in the total lag of 11 to 26 years.

The present value of total cost of research and adoption is assumed to range from $30m to $60m. The lower value of $30m represents the cost of funding a research agency such as the IA CRC for a six-year period. This cost should represent a reasonable lower bound. A 5% discount rate was used and the time horizon for the evaluation was 25 years.

5.3 Potential returns on research investment

The BCRs and NPVs are presented in Tables 5.1 and 5.2 respectively. The ratios ranged from 1:1 up to 24.9:1, and the NPVs range from $5m to $718m, depending upon the scenario. Generally, the highest returns were associated with high avoidable costs, short adoption lags, and low research costs.

To put these results in these tables in some perspective, the IA CRC established targets to reduce invasive animal costs by between 5% and 10%. Using an adoption lag scenario of 10 years and research and adoption costs of $30 to $40m, the benefit–cost ratio from successful research would range between 5.1:1 and 13.6:1. The NPV for these same scenarios would range between $163m and $377m.

Even with the most pessimistic scenario of Tables 5.1 and 5.2, investment in research is economically desirable and this is perhaps the most interesting aspect of the results. More specifically, with an adoption lag of 20 years, and the assumption that only 2.5% of the total loss is avoidable, the BCR is still above 1.0 and the NPV is still positive.

However, these results may still have underestimated the economic desirability of the research. We are grateful to an anonymous reviewer for developing the following arguments.

- The benefits from biodiversity protection are omitted and these may continue well beyond the specified time horizon of 25 years.
- The benefits to agriculture from permanently reducing some commercial pests would also extend well beyond 25 years.
- The discount rate of 5% may possibly be too high. If so, the ratios and NPVs are underestimated.

The implication of these arguments is that we have underestimated the net benefits. So some investments may still be economically desirable even though they are unprofitable with the given lags, the given avoidable costs, a 25 year time horizon and a 5% discount rate.

Table 5.1: Benefit–cost ratios of potential research benefit outcomes

	Avoidable cost (%)					
	2.5%	**5.0%**	**7.5%**	**10.0%**	**12.5%**	**15.0%**
(A) Adoption lag 5 years						
Costs ($m)						
30	4.2	8.3	12.5	16.6	20.8	24.9
35	3.6	7.1	10.7	14.3	17.8	21.4
40	3.1	6.2	9.4	12.5	15.6	18.7
45	2.8	5.5	8.3	11.1	13.9	16.6
50	2.5	5.0	7.5	10.0	12.5	15.0
55	2.3	4.5	6.8	9.1	11.3	13.6
60	2.1	4.2	6.2	8.3	10.4	12.5
(B) Adoption lag 10 years						
Costs ($m)						
30	3.4	6.8	10.2	13.6	16.9	20.3
35	2.9	5.8	8.7	11.6	14.5	17.4
40	2.5	5.1	7.6	10.2	12.7	15.2
45	2.3	4.5	6.8	9.0	11.3	13.6
50	2.0	4.1	6.1	8.1	10.2	12.2
55	1.8	3.7	5.5	7.4	9.2	11.1
60	1.7	3.4	5.1	6.8	8.5	10.2
(C) Adoption lag 15 years						
Costs ($m)						
30	2.7	5.5	8.2	10.9	13.7	16.4
35	2.3	4.7	7.0	9.4	11.7	14.0
40	2.0	4.1	6.1	8.2	10.2	12.3
45	1.8	3.6	5.5	7.3	9.1	10.9
50	1.6	3.3	4.9	6.6	8.2	9.8
55	1.5	3.0	4.5	6.0	7.4	8.9
60	1.4	2.7	4.1	5.5	6.8	8.2
(D) Adoption lag 20 years						
Costs ($m)						
30	2.2	4.3	6.5	8.7	10.8	13.0
35	1.9	3.7	5.6	7.4	9.3	11.1
40	1.6	3.2	4.9	6.5	8.1	9.7
45	1.4	2.9	4.3	5.8	7.2	8.7
50	1.3	2.6	3.9	5.2	6.5	7.8
55	1.2	2.4	3.5	4.7	5.9	7.1
60	1.1	2.2	3.2	4.3	5.4	6.5

Table 5.2: Net present values of potential research benefit outcomes ($m)

	Avoidable cost (%)					
	2.5%	**5.0%**	**7.5%**	**10.0%**	**12.5%**	**15.0%**
(A) Adoption lag 5 years						
Costs ($m)						
30	95	219	344	469	594	718
35	90	214	339	464	589	713
40	85	209	334	459	584	708
45	80	204	329	454	579	703
50	75	199	324	449	574	698
55	70	194	319	444	569	693
60	65	189	314	439	564	688
(B) Adoption lag 10 years						
Costs ($m)						
30	72	173	275	377	478	580
35	67	168	270	372	473	575
40	62	163	265	367	468	570
45	57	158	260	362	463	565
50	52	153	255	357	458	560
55	47	148	250	352	453	555
60	42	143	245	347	448	550
(C) Adoption lag 15 years						
Costs ($m)						
30	52	134	216	298	380	462
35	47	129	211	293	375	457
40	42	124	206	288	370	452
45	37	119	201	283	365	447
50	32	114	196	278	360	442
55	27	109	191	273	355	437
60	22	104	186	268	350	432
(D) Adoption lag 20 years						
Costs ($m)						
30	35	100	165	230	295	360
35	30	95	160	225	290	355
40	25	90	155	220	285	350
45	20	85	150	215	280	345
50	15	80	145	210	275	340
55	10	75	140	205	270	335
60	5	70	135	200	265	330

6. Discussion and conclusions

6.1 A review of the results

We have estimated the values of the economic losses due to pests in Australia, and the expenditures on management, administration and research to mitigate these losses. The findings are now summarised so that they can be set in context and interpreted in the remainder of this chapter.

An economist interprets gains and losses in terms of changes in welfare to the community as a whole, models them as changes in net benefit, and measures them as changes in economic surplus. The economic surplus model was therefore applied to value the impact of pests on agricultural commodities. The basic data for this model were the prices and quantities, and slopes of supply and demand curves, for each commodity the shifts in the supply curve, and the distribution and abundance of each pest. The annual losses by groups of agricultural industries are:

Industry	**$m**
Beef	187.7
Wool	71.3
Lamb	20.0
Grains	5.9
Total	**284.9**

The losses in the grain industry are higher than this value of $5.9m per year when there are mouse plagues. McLeod (2004) estimated the yearly cost of these mouse plagues to be $22.8m as the annual equivalent of a plague every 10 years in the mouse–prone regions.

The losses in horticulture were estimated as the losses of production plus the associated control costs. They were adapted from Tracey et al (2007). The total annual losses were estimated to be $313.1m, and the losses by industry were:

Industry	**$m**
Wine/grape	120.8
Pome fruit	85.0
Stone fruit	58.4
Nut	48.9
Total	**313.1**

The overall loss in agriculture, including horticulture, is therefore $620.8m ($284.9 + 22.8 + 313.1). This overall cost can be disaggregated by individual pest to give:

Pest	**$m**
Birds	313.1
Rabbits	206.0
Wild dogs	48.5
Mice	22.8
Foxes	21.2
Feral pigs	9.2
Total	**620.8**

The total annual expenditure on management, administration, and research was estimated to be $122.7 m for Australia as a whole.

The direct economic impact on production and governments is therefore:

Economic impact on	$m
Agriculture	307.7[1]
Horticulture	313.1
Management, administration and research	122.7
Total ($m)	**743.5**

[1] Includes $284.9 for agriculture plus $22.8m for mice.

The losses in agriculture and horticulture are estimated as potential total gains if there were no pest damage. So the results assume that the total loss in each industry can be avoided. To explore the possibility that only a portion of these totals can be avoided, we undertook a benefit–cost analysis of a range of scenarios concerning investment in research and management to improve pest control. With a pessimistic scenario that only 2.5% of the losses can be avoided, the benefit–cost ratio of the investment still has a ratio over 1.0 so the benefits of further research exceed the costs at this low percentage of avoidable losses.

6.2 An interpretation of the results

These results, as the annual costs due to invasive pests, may be summarised as follows:

- Losses in agriculture total at least $308m.
- Losses in horticulture total at least $313m.
- Governments and landholders spend at least $123m to manage pests.

However, numerical values of losses are only a snapshot at a given time. They will change as climate changes, as land uses change, as government budgets change, and with the occurrence of pest plagues. But the values do indicate that:

- invasive animals are a significant problem to agriculture
- losses in agriculture and horticulture are spread across a large number of industries
- many pests cause significant levels of damage
- considerable sums are spent each year to control them
- the community has a considerable commitment to managing pest animals.

The economic importance of invasive animals in general indicates a clear need for the management capacity of government agencies and landholders to be enhanced.

6.3 Strengths and weaknesses

The main strengths of this report include the application of:

- economic surplus models to assess agricultural impacts
- current agricultural data
- current data on the distribution of pests
- current data on management, administration and research costs
- benefit–cost analysis to examine the differences between avoidable and total losses.

The main weaknesses of this research, like all such studies, rest on the lack of data and the challenges in applying the chosen methods.

- Due to a lack of data, we could not estimate the impact of birds on horticulture as a change in economic surplus, so we have left these costs as a loss of total revenue.
- Some expenditure on management, administration and research remain unavailable.

With appropriate data, these weaknesses can be overcome.

6.4 Discussion

These results can now be set in the context of closely-related studies, concerning the size of agricultural losses and the costs of landholder expenditures on control.

Losses of agricultural production in 2002 over the ten major vertebrate pests in Australia totalled $420m (Bomford and Hart, 2002) and losses in 2004 over eleven major pests totalled $374m (McLeod 2004). The present estimate for losses over six pests is $621m. These figures are, of course, based on rather different groups of pest, different methods of estimation and estimated at slightly different times. However, the size of the agricultural loss is significant in all three studies, and the inclusion of the impact of birds in horticulture may have led to the increased size of the current estimate.

The expenditures of landholders are always difficult to estimate. As we noted in Chapter 4, the ABS (2008) estimated that total, Australia-wide on-farm expenditures on pest management totalled $768m during 2006–07. According to the bureau there are 150,403 farm businesses nationally, so the expenditure per farm is $5100 per year. This comprises costs that vary with production and costs that are fixed over all levels of production. The survey collected no information on production losses.

We have used a value of $325 per farm for the costs that are fixed over all levels of production, as explained in Chapter 4. The costs that vary with production are already netted out of the agricultural losses through our use of the surplus model. The basic model of Figure 2.4 rests on a shift of the supply curve for agricultural production from S_0 with existing pest levels to S_1 with a reduction in pest levels. As we discussed in Section 2.1.3, pest control expenditure is part of the cost of production so is included in the marginal costs of curves S_0 and S_1. So our net change in surplus incorporates, by netting out, this part of the ABS expenditures of $5100 per farm.

6.5 Future research

This study could be extended:

- to identify biophysical damage functions to better understand the size and nature of pest problems
- to evaluate the returns from investment in specific techniques of management to shift the dispersal and abundance levels of pests
- to evaluate the returns from investment in research and development by research organisations such as IA CRC individual research projects.

The results show that $123m is spent each year on research, administrative and control, while the agricultural loss is $621m. So it is possible that too little money is being spent on the management of invasive pest animals. Benefit–cost analyses of further specific expenditures therefore seem warranted.

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