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PUBLIC POLICY ON CATTLE TICK CONTROL IN NEW SOUTH WALES*

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An economic problem exists in the allocation of resources to cattle tick control. The decisions of private individuals on tick control are unlikely to result in a desirable allocation from society's viewpoint because of market failure. Such market failure will be due to significant externalities, risk and economies of scale in cattle tick control and ignorance of tick control by producers. Government involvement is justified to achieve a better allocation of resources than would otherwise occur.

Choice of the desirable level of Government involvement and of the best control strategy will depend upon reduction of the decision problem to a choice between a combination of a small number of strategies and policy instruments and empirical evaluation of the benefits and costs of these. The difficulties of doing so are discussed.

The distribution of benefits is analyzed. Arguments are presented for adopting the principle that the beneficiaries of tick control should pay. Based on this principle methods of raising finance for cattle tick control in New South Wales are analyzed and recommendations made.

The results are presented of a cost-benefit study on cattle tick control. It was assumed that the current level of Government involvement would continue and the study sought to determine whether eradication was a more economic policy than the present control policy. Eradication was shown to be most probably superior to continued control. The use is demonstrated of subjective probabilities determined by groups.

1 INTRODUCTION

The total cost of the cattle tick (*Boophilus microplus* (*Canestrini*)) in Australia in 1972–3 has been estimated at approximately $42 million [6]. As possibly with all diseases and pests, many methods and levels of control or eradication of cattle ticks are available to the policy maker. This paper is based upon the author's experience in undertaking a cost-benefit study on alternative policies in the control of the cattle tick in New South Wales [16]. Knowledge gained on public policy regarding the cattle tick should have wider application to the study of policy on other pests and diseases.

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The cost-benefit study was undertaken because of current Government concern at the increasing public expenditure on cattle tick control and the presence of acaricide resistant ticks in the quarantine areas of New South Wales.

This paper extends the analysis of policy on cattle tick control beyond that contained in the cost-benefit study [16]. It argues qualitatively the need for Government intervention in the allocation of resources to tick control and examines a range of strategies in terms of their economic efficiency and equity. The strategies examined include policies of reduced control not considered in the cost-benefit study or by the Cattle Tick Control Commission [6].

2 BACKGROUND ON THE CATTLE TICK

Cattle ticks may cause economic losses through tick worry (anaemia and/or loss of appetite), tick fever (of which *Boophilus* is the sole carrier), and damage to hides. The cattle tick has rapidly become distributed over a large area of Northern Australia since its introduction to Australia, probably in 1872, through Darwin [35]. Its distribution is shown in figure 1.

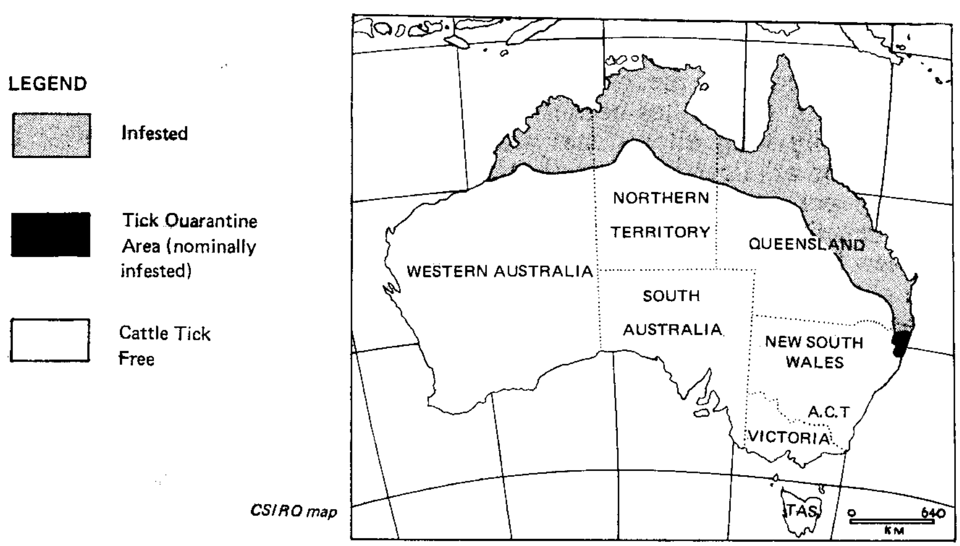

Figure 1—*The tick infested areas of Australia*

This area currently supports approximately 30 per cent of the Australian beef cattle population. The cattle tick entered New South Wales in 1906 despite efforts commenced in 1902 by the New South Wales Government to keep it out.[1]

Three effective methods of control are available—dipping or spraying of cattle and other hosts with an effective pesticide (known as an acaricide) [24]; use of tick resistant cattle [39]; and strategic pasture spelling [38]. The last is impractical on many farms because of the long period for which paddocks have to be locked up. Dipping is the most extensively used control measure. Tick fever may be prevented by vaccination of susceptible cattle or natural infection of herds by ticks in tick fever endemic areas (the latter method requires maintenance of a tick population).

The approaches by governments to the control of ticks has differed substantially between States. In Queensland control has primarily been the responsibility of the cattle owners. Government participation has been mainly concerned with the control of stock movements, particularly the movement of cattle from tick-infested to tick-free country, research, the registration of acaricides and with extension. In the Northern Territory and Western Australia, government activity has been limited largely to the supervision of cattle movements to tick-free country or across state borders where required. Partly because of the fear of tick fever and the absence until recently of a tick fever vaccine, tick numbers have been maintained at reasonable levels in Queensland to ensure reinfection of cattle.

In New South Wales policy has been defined by Davies [8]. Eradication has always been the objective and tick and tick fever control have been in the hands of the Government. It provides all treatment facilities, determines when cattle shall be treated and rigidly controls cattle movements between Queensland and the Tick Quarantine Area of New South Wales (T.Q.A.), between gazetted areas within the T.Q.A. and between the T.Q.A. and tick-free country in New South Wales. The control programme and several attempts at eradication have been based entirely on dipping. In contrast to Queensland an intensive dipping programme has been maintained over all cattle in the more ecologically favourable area of the T.Q.A. since 1961 with the result that tick numbers are small.[2] Tick fever is not endemic to New South Wales. The New South Wales Government (with some assistance from the Australian Government for research and interstate quarantine) has paid for all control work since the inception of the Board of Tick Control in 1923. In doing so the Government has adhered to a principal enunciated by Mr N. W. Fletcher, police magistrate and one-man Royal Commission appointed by the New South Wales Government in 1918:

"... the eradication of the pest is a matter for State and not only local interest and the cost should be borne by the State and paid from Consolidated Revenue" [8, p.120]

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[1] Seddon [35] has described the spread of the cattle tick and tick fever from its first introduction into Australia. Wilkinson [38] has defined the distribution and abundance of the cattle tick.

[2] Relatively few infestations have been found since 1965 and have declined from 64 in 1965–6 to 14 in 1973–4. Most of these infestations have been light.

Since that time Government expenditure on tick control in New South Wales has risen steadily and in 1971–2 the New South Wales Board of Tick Control employed 600 people and spent close to $4 million.

With these major differences in policy between New South Wales and Queensland in focus, the following sections give consideration to three major and interrelated questions; to what extent should the New South Wales Government be involved in cattle tick control; what is the best control strategy (including eradication); and who should pay for cattle tick control?

3 GOVERNMENT INVOLVEMENT IN CATTLE TICK CONTROL

3.1 Reasons for Government Involvement

This section establishes the grounds upon which government involvement in disease or pest control may be justified for the efficient allocation of resources. Some consideration is also given to distributional arguments for government involvement.

On welfare economic grounds some form of government intervention in the private sector may be justified if it can be shown that the allocation of resources to cattle tick control both in amount and type is significantly different from that considered desirable by society.

In this section the assumption is made that beef and dairy production are continuous, increasing but marginally diminishing functions of tick control inputs (dipping, resistant cattle and pasture spelling) so far as losses from tick worry and hide damage are concerned. In tick fever endemic areas high levels of control can result in mortalities from tick fever unless tick fever vaccine is used.[3]

As Freebairn [15] has noted, in the absence of government intervention producers would allocate resources to cattle tick control "such that the marginal monetary or utility gain perceived by them approximates the marginal or opportunity costs to them as individuals of devoting resources to these activities". These private benefits and costs may not be the same as the benefits and costs seen by society where society is seen as an aggregate of producers and consumers.

Such a divergence between private and social benefits and costs may arise for several reasons:

(i) Externalities in tick control.

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[3] For several reasons the assumption of a continuous and increasing factor/product function may not be satisfied. Dipping is a lumpy input in that it is carried out at intervals and timing is a most important consideration. Tick control methods also have certain joint products. Dipping controls other external parasites such as lice and bush ticks (*Haemaphysalis longicornis*) on the New South Wales North Coast. Other operations such as vaccinating, inspection of cattle and culling can be performed at the same time as dipping. *Bos indicus* breed cattle have other desirable and undesirable characteristics besides resistance to cattle ticks and similarly pasture spelling. However the assumption will largely be satisfied.

(ii) Cost economies in tick control activities.

(iii) Ignorance on the part of private individuals which causes inefficiencies in both the private and public application of tick control.

(iv) Differences in the attitudes of private individuals and society to risk and consumption over time.

(v) Distortions in the prices of tick control services caused by other government measures.[4]

3.1.1. Externalities

Externalities are costs or benefits which individual decision-makers impose or bestow upon others by their actions but for which they suffer no penalty and or no reward. In consequence these decision-makers exclude consideration of these externalities when arriving at decisions. The existence of externalities in cattle tick control means that the independent actions of individual farmers undertaking control will not, except by great coincidence, correspond to what would be considered socially desirable.[5]

Space will be devoted here to an examination of the nature of these externalities and their importance in causing misallocation of resources. All significant externalities arising from tick control involve interaction between cattle producers.[6] Externalities between cattle producers and consumers of meat or dairy products or others in the community due to ticks or tick control are probably insignificant.[7]

Corresponding to Mishan's definition of an externality [22, p. 105] the number of ticks on property A will have some impact on beef and dairy production on property B by influencing the number of ticks on property B. Efforts by farmer B to control ticks will reduce to some extent either the number of ticks on property A or the risks of infestation of property A if it is currently free of ticks.

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[4] Externalities (as described here) cost economies, ignorance and certain risk situations are causes of what Bator [3] describes as "market failure"—"the failure of a more or less idealized system of price-market institutions to sustain "desirable" activities or to stop "undesirable activities". Note that externalities here are not defined to include cost economies as Bator defines them. On the other hand market failure is given a wider meaning than that used by Arrow [2]—the failure of markets to exist. Bator also includes in his definition the failure of markets to give the right signals, to give incentives or to operate efficiently because of a lack of operators or legal, institutional or technical problems.

[5] Externalities are strictly defined in terms of their role as barriers to the attainment of Pareto optimality. The concept has therefore arisen of the Pareto relevant externality, the existence of which is dependent upon their being:

(a) interdependencies between the actions of different individuals;

(b) potential for the beneficiary to bribe the benefactor and for both to gain from this trade;

(c) barriers to such mutually beneficial trades taking place.

[6] Also involved are owners of other suitable hosts of the cattle tick if these other hosts do in fact exist [6, p. 80–82].

[7] Levels of acaricide residues resulting from tick control, for example, are low and chlorinated hydrocarbons, the principal villains in the residue problem, are no longer used in cattle tick control in Australia.

Depending upon the intensity of control adopted by a farmer relative to his neighbours, he could be viewed as imposing an external cost on the neighbours by not undertaking enough control or as providing an external benefit by undertaking some control. Control at any level will be viewed as providing external benefits throughout this article.

Individual farmers are not able to appropriate the external benefits of their tick control efforts for two reasons.

(i) no legal or technical bases exist which would allow farmers to prove the magnitude and origin of external benefits they may claim to have provided and for which they claim compensation;

(ii) tick control has characteristics of the public good and its associated "free rider" problem.

The first reason corresponds to Meade's "unpaid" factor case [21, p. 358]. No means currently exist for the measurement of the benefits provided by one farmer to another in controlling ticks. Even if it were possible to estimate these benefits with acceptable confidence to cover every property situation, it is likely the research costs of doing so would be far higher than the value of the externalities involved. But a major problem also exists in law in that the law is unlikely to compensate a farmer for providing an unsolicited benefit to another farmer. That is no liability rule is likely to be acceptable and it will be left to the beneficiary to bribe the benefactor. Even if perfect information was available to indicate the magnitude of benefits provided, no litigation would be likely to result since the external benefits tend to be reciprocally provided. While without trade the resultant allocation of resources would be non-optimal, farmers providing external benefits to each other from tick control are likely to see the value of these benefits as offsetting each other.[8]

Taking the second point, public good externalities are also involved because control efforts by one person will invariably provide benefit to more than one person. The condition specified by Samuelson [34, p. 387] for a public good is generally satisfied. That is, the consumption of tick control benefits by one person does not reduce the amount of these benefits available for consumption by another. To some extent exclusion of non-payers would be possible but only in the case of neighbours. Cattle held in paddocks on the boundary with non-paying neighbours could be kept segregated and not dipped as much as those on boundaries with paying neighbours and with the rest of the property. Such exclusion would be very expensive however because of the lumpiness of tick control inputs. It is cheaper to dip all cattle so that cattle may be moved around the property as required. But people other than neighbours will generally stand to gain as much or more in external benefits from a farmer's tick control efforts. Ease of movement of cattle over long distances places herds over a wide area under risk of infestation from an infected herd. The benefits of tick control will therefore be distributed widely. So even though it may pay beneficiaries from tick control to bribe the benefactors to intensify control efforts the "free loader" incentive will always exist for each individual beneficiary to wait until some other beneficiary does the bribing and so reap the benefits at zero cost. Despite

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[8] This is demonstrated by Meade [21, pp. 358–60].

the expensive possibility of exclusion such public good characteristics would result in suboptimal allocation of resources to tick control even if perfect knowledge were available of the interproducer benefits provided by tick control [26, p. 939].

3.1.2. Cost Economics in Tick Control

Economies of scale and indivisibilities exist in the control of cattle ticks. The principal ones lie in the provision of skilled labour and laboratory staff to carry out inspections of cattle dipping, the checking of dip concentrations and to educate farmers in tick control. Substantial economies also exist in the conduct of research by one or more large organizations. Diseconomies of size also possibly exist in reduced staff motivation when staff numbers of the order of six hundred are involved as in the Board of Tick Control.

Government departments or statutory organizations are not the only organizations capable of capturing such economies of size. In Queensland, for example, chemical companies which market acaricides also provide extensive laboratory services for dip wash analysis.

3.1.3. Ignorance

Even though individual producers may reap all the benefits of tick control activities in a riskless world and pay all the costs (shown not to be the case) they will invariably under or over invest in tick control because of imperfect knowledge. In particular it might be argued that producers underestimate the private benefits of tick control. Production losses from tick worry and hide damage are not readily detectable. This is likely to be the case in Queensland. Ignorance of the benefits of tick control is undoubtedly widespread in the T.Q.A. of New South Wales. It is difficult to say what would happen if the responsibility of control was handed over to farmers in New South Wales. Some farmers would probably underestimate the benefits to them and rapidly move to a level of underinvestment in tick control measures. Ohter farmers would probably overestimate the benefits they had been receiving.

Social losses resulting from ignorance take a variety of forms. In private tick control efforts farmers may choose an incorrect level of control resulting in greater tick losses; greater acaricide resistance problems, etc. In the case of tick control by government, farmers in the absence of education campaigns will be even more ignorant of the benefits of control. In these circumstances, social losses from non-co-operation by farmers tend to increase as represented by increased costs of litigations and other forms of regulation enforcement.

Government measures aimed at reducing the social losses from producer ignorance include the provision or improvement of education and extension on the benefits and costs of alternative tick control strategies; subsidies on tick control inputs; regulations requiring greater use of control inputs; and control by government itself. Private corporations, principally chemical companies, may also become involved in education of cattle owners on the desirability and methods of cattle tick control in the course of marketing their products. This occurs substantially in Queensland.

3.1.4. The Bearing of Risk

Tick control results in savings in costs. For a variety of reasons the magnitude of these savings will be uncertain. Given these risks and assuming cattle owners are risk averse, then, in the absence of other causes of market failure, cattle owners will over allocate resources to tick control. This assumes that in the absence of government intervention, markets for the spreading of risks such as insurance or common stocks would not exist. Government involvement may be justified to correct such misallocation.

This section examines the nature of the risks due to ticks or tick control and the forms which government intervention to mitigate the effects of risk may take.

(a) *The Nature of Risks Involved in Tick Control*

The magnitude of benefits and costs of tick control and eradication are based upon the occurrence of a variety of uncertain events. Since tick numbers and tick damage in cattle are dependent upon uncertain variables such as weather, cattle numbers, etc., then it follows that the future payoff from a selected level of tick control will also be uncertain. Uncertain costs also exist in tick control, for example, the possibility of poisoning from incorrect dip concentrations.

Uncertainty will apply to externalities as well as internal benefits and costs. Tick control on property A will confer uncertain benefits on property B. Chemical control now will have uncertain effects on the future stock of effective acaricides.

Uncertainty applies in particular to the payoff from tick fever vaccination since the occurrence of tick fever is such an uncertain event. Very high losses can result from tick fever making this risk most important in tick control.

(b) *Methods of Government Intervention*

Arrow [1] argues that governments may reduce the misallocation of resources due to risk (always in a second-best solution) by:

(i) improving markets for risk bearing which in this case do not exist. Such market failure will generally be caused by moral hazard and/or transaction costs;

(ii) by taking over control themselves, i.e. by undertaking public investment in a project.

Arrow implies that intervention by government to improve a market for risk spreading will only improve the allocation of resources if governments are able to reduce transaction costs or reduce problems of moral hazard. The risks of tick control are largely unidentifiable and therefore uninsurable. However, insurance could be (and is) provided for some sorts of losses resulting directly from ticks. The feasibility and effects of such insurance schemes are discussed in a later section.

Following the arguments of Arrow [1], governments should act neutrally to risk in considering public investment in cattle tick control. Under such circumstances the appropriate discount rate to be used will be an opportunity cost one—the best rate available in either alternative government or in private investments after subtraction of a risk premium. Of course government could choose a discount rate as a matter of social policy unrelated to returns in alternative investments [1, p. 241]. Such a philosophy of choice is based upon the notion that individual preferences as revealed by market behaviour bear no necessary relationship to society's preferences for government action and are therefore of no normative significance for government investment decisions. For example, individuals possibly expect governments as representing society to be more altruistic towards future generations than they would be themselves in their private market decisions. They would therefore expect governments to adopt a lower discount rate even allowing for a risk premium.

The possibilities of introducing various forms of insurance are discussed later. However, public investment to control cattle ticks does not seem justified on grounds of risk spreading alone, except in the conduct of research where there is undoubtedly a case. The risks of tick worry losses, etc. are not great.

3.1.5. Compensating Assistance

Considered here are arguments for adjustments to the resources devoted to tick control to offset the effects of other distortions inherent in the existing market structure. Arguments have been advanced in the literature[9] for government intervention to compensate for two types of distortions:

(i) distortions in the prices of tick control inputs caused by government subsidies or tariffs instituted for other than economic reasons;

(ii) distortions in the derived demand for tick control inputs due to a lower (or higher) level of effective protection afforded the cattle industries than afforded other industries.

Compensatory assistance could be of relevance since the beef cattle industry probably receives a negative rate of protection.[10] Further discussion of such a wide and controversial subject is beyond the scope of this paper.

3.1.6. Distributional and Equity Failure

Changes in government policy directly influencing the control and/or eradication of cattle ticks may be advocated on the grounds that the existing policy yields an inequitable distribution of the costs of ticks or of their control. Clearly the distributional effects are interrelated with the allocative effects discussed above. The objective here is to focus on equity effects.

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[9] Freebairn *op. cit.* and Rural Policy in Australia [36, chap. 3 and chap. 5].

[10] For a definition of effective protection *see* [24].

In a Queensland type control situation costs to the individual producer of an outbreak of tick fever or of tick worry losses may be difficult to foresee and are often very costly; particularly in marginal tick area. The relationships existing between both tick worry and tick fever and fluctuating factors such as numbers of ticks, seasonal conditions, nutritional state of the host and resistance status of the host suggest that, at least in some areas, ticks may cause extensive income losses for a few producers and relatively smaller costs for other producers. For these reasons, society may consider the equity effects of tick fever outbreaks and tick infestations under a Queensland type situation as undesirable and this would justify a policy change.

There would seem to be a number of ways in which government could mitigate the personal consequences of cattle ticks. Policies designed to eradicate ticks provide a longer term option. Other policy actions include compulsory or voluntary insurance schemes. The present policy in New South Wales in fact, effectively eliminates inequity due to the existence of ticks but contains inequities in the financing of tick control. These are discussed in section 5.

3.2 Remedies for Market Failure—Policy Measures

This section focuses on potential government policies designed to improve the allocative efficiency and distributional equity of resources used for the control or eradication of cattle ticks. Six types of policy instruments are discussed.

(i) Systems of Property Rights.
(ii) Tick Loss Insurance.
(iii) Input Subsidies.
(iv) Output Subsidies.
(v) Regulations.
(vi) Producer Education.

Clearly at any one time it may be desirable to employ a combination of these policy instruments.

3.2.1. Property Rights

In theory part of the external benefits of tick control could be appropriated by establishing property rights on tick free animals. The basis for accepting cattle as tick free could be either inspection and dipping or dipping on its own.[11] In addition to the costs of inspecting or dipping cattle, costs would be involved of segregating cattle at saleyards and of maintaining facilities tick free.

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[11] Market differentials do exist in the T.Q.A. at the moment between animals which have received different numbers of dippings prior to sale. But these are a reflection of government regulations on the number of dippings required prior to movement of cattle within or to outside the T.Q.A.

A market would be unlikely to differentiate efficiently (if it did at all) between tick free, infested cattle and unknown status cattle because information on the marginal cost of introducing tick infested versus tick free cattle would be required. As indicated earlier this is not available. Further, such a market is unlikely to significantly reduce the non-appropriation problem since:

(i) a large number of cattle are moved off properties for purposes other than sale and these may infest areas such as roads or abattoirs;

(ii) ticks may be transported onto other properties by casual hosts, such as wallabies, dogs, birds, etc., by wind, water or on vehicles or may move over ground themselves through fences.

In practice therefore property rights are unlikely to provide any solution to the externality problem.

3.2.2. Tick Loss Insurance

Insurance schemes against production and other losses of an uncertain nature caused by ticks would be instruments to improve the market for risk bearing.

Insurance against losses from tick fever is likely to be the easiest to provide and in fact is provided in New South Wales through the Cattle Compensation Fund to which graziers pay a compulsory levy. Change to a separate and voluntary scheme for tick fever would be more desirable from an allocative viewpoint. However, it would raise transactions costs by some amount which would probably be small.

Insurance against all other production losses from ticks is likely to be impossible because of the immense difficulties in identifying and quantifying expected losses from tick worry and hide damage. Verifying claims for damages as being caused by ticks would also be very difficult. Losses from tick worry will generally be correlated with, but inseparable from, poor seasonal conditions.

Certain types of insurance against loss of profits due to quarantine and private control costs in the case of a tick fever or tick outbreaks could also be considered. Again difficulties in assessing claims could render such insurance unworkable.

Voluntary insurance against tick fever losses could be valuable in conjunction with spot eradication of tick fever infestations (as in New South Wales) and also with the use of tick fever vaccine (as in Queensland). In the latter case, a farmer would simply pay a premium for insurance based upon the expected cost per beast of market value compensation assuming that his cattle were not vaccinated. The premium would also include the transactions cost of operating the insurance scheme. The farmer would then make his own choice as to whether he vaccinated or insured himself. Transaction costs could render insurance in a Queensland situation unworkable since probabilities of infestation and tick fever would depend directly upon control policies adopted by the farmer and his neighbours.

Moral hazard may seem a problem in introducing such an insurance scheme. Introduction of an insurance scheme could result in a reduction of tick fever control by farmers because of a reduction in demand for the influence control measures have in reducing risks due to ticks. This does not represent a problem of moral hazard however. Insurance is simply improving the allocation of resources in this case. It will reduce the problem of allocating resources to tick fever control for the individual to one of comparing the savings in insurance premiums with the cost of control. The insurance premium will equal the expected value of losses plus transactions costs of running the insurance scheme. Previously the individual can be thought of as having compared the certainty equivalent of tick fever losses he has avoided with the cost of control. This certainty equivalent would be greater than the expected value of these losses for a risk averse farmer hence resulting in a greater allocation of resources to tick fever control than if insurance were provided.

It is unlikely that such insurance would be provided by private insurers. As pointed out earlier, the desirability of a government introducing such insurance schemes, rests on the ability of the government to reduce transaction costs from the level which would apply to a private insurer and down to a sufficiently low level to make insurance worthwhile.

3.2.3. Input Subsidies

If property owners in the T.Q.A. made their own decisions on the type and intensity of tick control to be adopted in their herds, the New South Wales Government could encourage a more optimal allocation of resources by subsidizing the cost of a variety of tick control inputs. It could, for example, subsidize the cost of acaricides, dipping facilities, labour and/or laboratory tests on dip concentration tests in order to encourage chemical control by farmers. It could subsidize the introduction of *Bos indicus* blood into herds. It could also possibly encourage control by the pasture spelling technique although this would be difficult. It could also subsidize the cost of tick fever vaccine. Government's contributions to research on cattle ticks and their control should also be counted as a subsidy.

It is highly unlikely that an input subsidy would even roughly compensate for the different external benefits bestowed by each beef or dairy producer undertaking tick control on others. If the decision for tick control rested with the individual he could, for reasons of ignorance, prejudice or non-profit maximizing objectives, fail to fully appreciate the desirable level of tick control even with lower costs of tick control.

From the point of view of administrative ease an input subsidy programme should be relatively straightforward although policing of the use of subsidized inputs for tick control would be difficult.[12]

Costs of running a tick control subsidy programme will depend upon the per unit subsidy and the quantities of subsidized inputs used. There may be considerable uncertainty about the quantities of resources that would be devoted to disease control under different levels of subsidies.

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[12] Such subsidized inputs could also be used for controlling bush ticks and lice. Of course this could also be a desirable use of resources from society's viewpoint.

The New South Wales Government does in fact subsidize inputs used in tick control to the extent of the full cost of these inputs. The use of subsidies is combined with regulatory enforcement of control procedures and the use of subsidies is largely looked upon as necessary to gain co-operation with the compulsory control programme.

3.2.4. Output Subsidies

An output incentive scheme would involve policy action to discriminate between tick free and tick infested properties and to pay an incentive for hides, beef and dairy produce emanating from tick free properties. Such a scheme would exaggerate the private benefits of tick control and would therefore result in an increased allocation of resources to tick control. It would therefore simply be, like input subsidies, a device to compensate for private misallocation due to net external benefits of tick control and ignorance.

The same uncertainty would surround the budget cost of output subsidies as with input subsidies. But added to this cost would be the administrative costs of inspecting and/or dipping cattle to provide certification of the tick free status of properties. The market place would be unlikely to create a premium for products from tick free properties since firstly, beef and dairy products from tick infested properties are not likely to be inferior in quality and secondly, the tick free status of a property is no guarantee of the soundness of a hide. Previously infested cattle with damaged hides could have been imported onto a tick free property.

Output subsidies are not likely to be as attractive as input subsidies in tick control.

3.2.5. Regulatory Tick Control

Regulatory tick control policies embrace regulations requiring specified programmes and levels of tick control. These regulations may be supplemented with education programmes and input and output subsidies. Regulatory policies have been the mainstay of pest and disease control policies in this country.

Regulatory tick control policies remove much of the decision-making power over the allocation of resources to tick control from producers to government. As "big stick" type policies they are in contrast to the "carrot" type policies discussed above.

The most basic form of regulatory tick control policy is a quarantine one, restricting the movement of cattle and/or requiring cattle moving over specified boundaries to be inspected and/or dipped. The movement of other hosts and objects potentially harbouring ticks may also be restricted. More rigorous regulatory policies may compulsorily require tick control of a certain type and intensity on all properties.

Such policies will reduce social costs arising from producers ignorance about the benefits, costs and methods of tick control, they will act to internalize the external benefits of tick control and they will reduce misallocation due to risk averse behaviour.

But regulatory tick control programmes have significant costs as is evident in New South Wales.

The cost of enforcement of regulations in New South Wales is high, not so much because of legal litigations but because of the employment of a large number of people as gatekeepers, senior assistants, etc. to police these regulations.

In addition, use of an intensive regulatory control programme has contributed to farmer ignorance of the value of tick control by reducing production losses to negligible levels over a long period of time. Resulting non-co-operation by farmers has led to a substitution of government employed labour for private labour in dipping operations. These costs of a regulatory programme could be partly overcome by farmer education.

The loss of personal freedom resulting from regulations should also be considered as a cost which is not associated with the other tick control strategies discussed.

3.2.6 Producer Education

Producer education is taken to include the extension of information on the identification of ticks, the benefits and costs of different levels of tick control and the explanation of government regulatory policies.

In a situation of privately organized control, if producer ignorance of the methods, benefits and costs of tick control is considered an important reason for under investment in control, then producer education attacks a basic cause. With a regulatory tick control programme, producer education may significantly reduce the costs of enforcing regulations and the costs of inefficiency in resource use because of ignorance itself and non-co-operation born of ignorance.

Experience with the extension of information on other forms of technology and management techniques suggests that producer education will be a slow process and it will not lead to positive action by all producers because of difficulties in communication and prejudice. Still, some producer education should lead to a greater allocation of resources to cattle tick control in a private control situation or alternatively lead to lower costs and greater efficiency in a regulatory control programme.

While producer education will increase the private allocation of resources to tick control so as to equate private marginal benefits and costs, it will not, of itself, encourage producers to include the external benefits accruing to other producers or reduce discounts for risk in their benefit-cost calculations.

3.3 The Desirable Level of Government Involvement

There is no doubt that some level of New South Wales Government involvement in cattle tick control is desirable. On balance external economies probably far outweigh diseconomies and underinvestment in cattle tick control would exist in the absence of government involvement for this reason.

Misallocation due to risk averse behaviour and tick fever would probably be insignificant in the case of privately organized control given the existence of tick fever vaccine and stockowners understanding of its use. On the other hand misallocation due to risk aversion and the risks of loss of profits from quarantine and spot eradication in regulatory control programmes could be significant enough to justify government provision of suitable types of insurance cover. Underinvestment in research and development on ticks and tick control due to risk would undoubtedly occur in the absence of government involvement. Underinvestment would be most apparent in basic research areas (tick ecology, functioning of tick resistance mechanisms, etc.) or on methods of control where because of public good externalities appropriation of benefits would be difficult. In areas such as acaricide synthesis a substantial amount of research and development is undertaken by private chemical companies. In this field patent laws allow effective appropriation of benefits of research.

Producer ignorance undoubtedly causes higher costs in the present situation of regulatory control and would probably result in additional costs of inefficiency and under-investment in control if this were privately organized. Cost economies certainly exist in the provision of some tick control services by government.

Some intensive forms of control such as eradication and biological methods (if the latter became available for cattle tick control) depend very much on government involvement for all the above reasons. In particular eradication programmes require co-operation by farmers and many other persons in intensive control efforts [31]. Because eradication of ticks is unlikely to be undertaken without government involvement, certain externalities sometimes associated with eradication programmes such as the destruction of wild life[13] are not likely to be a problem unless government also fails to take them into account.

Biological methods involve very high initial costs of research and development and the benefits are spread over a large area with little opportunity for appropriation [7].

Even if a less intensive control policy were adopted involving private decisions on control strategies, government involvement at a level greater than that existing in Queensland is considered desirable. Queensland policy provides no means of overcoming under investment in cattle tick control caused by externalities.

[13] Eradication programmes may require the destruction of wildlife because they are favourable hosts to the cattle tick. Considerable controversy surrounded the killing of many thousands of white tailed deer (*Odocoileus virginianus*) in Florida, U.S.A. in an attempt to eradicate the cattle tick in that area [19, 26]. In Australia the red deer (*Cervus elaphus*) which is found in the Brisbane Valley, the Water Buffalo (*Bubalus bubalis*), Banteng cattle (*Bos sondaicus*) and brumby horses are favourable hosts for the cattle tick. Their destruction would possibly be necessary if eradication was to be successful in an area in which they were found [6, p. 80].

4 FINANCING OF CATTLE TICK CONTROL

Both efficiency of resource allocation and equity would seem to require adoption of the principle that the beneficiaries of cattle tick control should pay the cost of control in proportion to the extent they benefit. This principle was adopted in Evans *et al.* [12, p. 43] and argued in the "Green Paper" [36, 5.214]. This section therefore considers the distribution of the benefits of cattle tick control in New South Wales and possible ways of financing control.

In the absence of government intervention it is evident from Queensland experience that stockowners will adopt some tick control measures. The effect of such control measures in comparison with a situation of zero control will be to lower the individual stockowners marginal costs of production and in terms of aggregate market performance this will result in a shift of the industry supply curves for beef and dairy products to the right. The Queensland situation indicates that hides would still be classed as "ticky" and would suffer a discount against clean hides. Government intervention to internalize externalities, compensate for risk averse behaviour and to reduce producer ignorance would further shift the supply curve to the right. If by such a policy ticks, and therefore hide damage, were reduced to negligible levels, then this would result in the shift of a quantity of hides from the "ticky" to the clean hide market.

The benefits of a cattle tick control strategy including government intervention to correct for market failure may be assessed in terms of the changes in producer and consumer surplus (with all their qualifications). This is illustrated with the aid of figures 2 and 3.

In figure 2 the supply shift for beef or dairy products will result in—

(a) a fall in the market price for beef or dairy products by P_oP_1, the amount depending upon the elasticity of demand and the extent of the supply shift;

(b) a rise in the quantity produced by Q_oQ_1, the amount depending again on the elasticity of demand and the extent of the supply shift;

(c) a gain to consumers measured by consumer surplus given by the area P_obcP_1. Consumers will include both domestic and overseas buyers;

(d) a rise (fall) in gross revenue to the cattle industry if the demand curve is elastic (inelastic);

(e) a change in producer surplus accruing to quasi fixed resources employed by cattle owners (land, some capital, etc.) measured by $(P_1cd - P_oba)$. Duncan and Tisdell [9] indicate the conditions under which there will be a net gain or loss;

(f) a net gain to society in beef and dairy product markets given by the area *abcd* less any Treasury contribution.

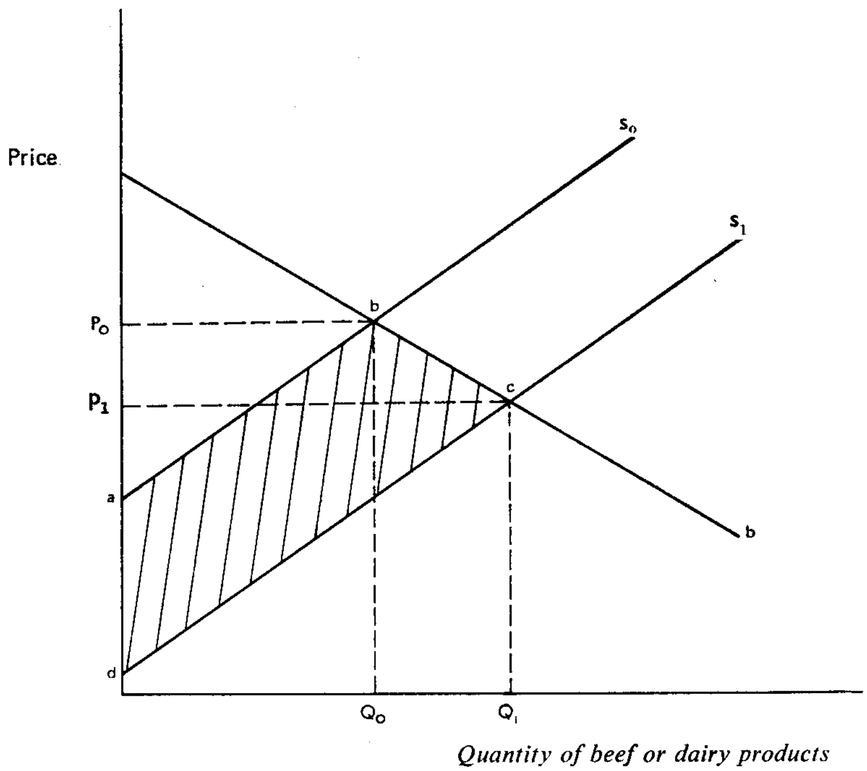

FIGURE 2: *Benefits of a reduction in tick worry and tick fever in the market for beef or dairy products*

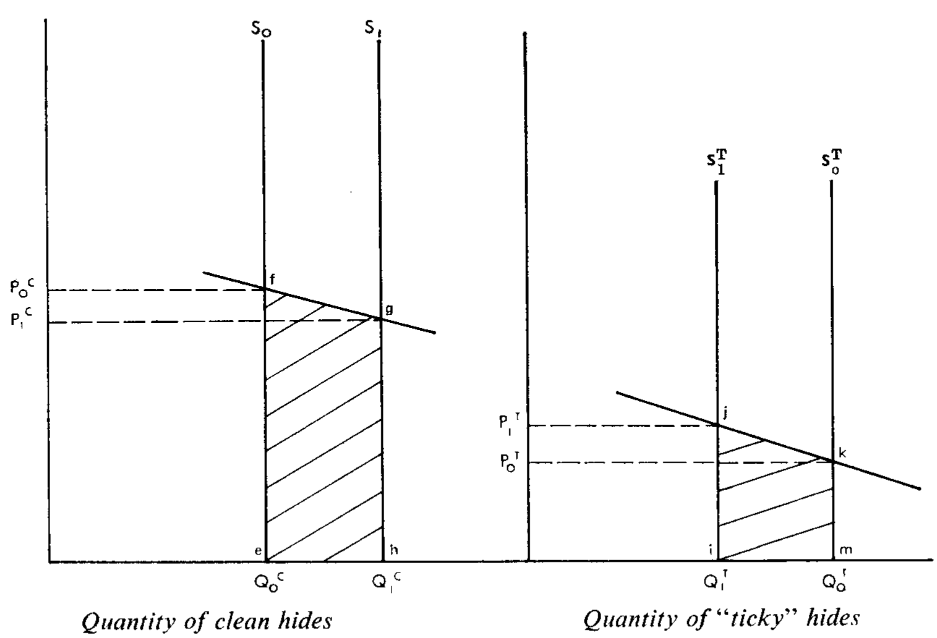

FIGURE 3: *Benefits from a reduction in tick damage to hides*

In figure 3 reduction of ticks to negligible numbers will result in a shift of hides from the "ticky" to clean hide markets plus an increase in the quantity of hides supplied whether "ticky" or clean because of the increased beef and dairy production shown in figure 2. This shift will result in—

(a) a consumer gain, measured by consumer surplus, is given by $(P_o^c fg P_1^c - P_1^T jk P_o^T)$: Again consumers will include domestic and overseas buyers;

(b) the change in producer surplus accruing to quasi fixed resources will be given by $(P_1^c gh - P_o^c fe) - (P_1^T ji - P_o^T km)$. If the supply of hides is completely inelastic as suspected then this will also be the change in gross revenue to the cattle industry;

(c) the net gain to society will be given by the area $(efgh - ijkm)$ (assuming the whole of any Treasury contribution will have already been subtracted from the net gain in the markets for beef and dairy products).

The total net gain to society will therefore be given by $(abcd)$ beef products market + $(abcd)$ dairy products market + $(efgh - ijkm)$ less any Treasury contribution.

In New South Wales, quarantine regulations and control within the T.Q.A. have effectively prevented the cattle tick from spreading to its potential ecological limit. Stockowners outside the T.Q.A. but within the area of potential tick distribution (APTD) and consumers of beef and dairy products receive benefits from these regulations. These benefits are equal to the producer and consumer surplus respectively, which would otherwise be lost if ticks occupied the whole of this APTD.

As noted above the distribution of the benefits arising from control of cattle ticks between producers, domestic consumers and overseas consumers depends largely upon the nature of the supply and demand curves for cattle products.

At the area of interest the aggregate demand curve for Australian beef has been largely export determined and highly elastic. In this situation any shift to the right in the supply curve of beef is likely to result in little change in the price of beef and therefore little gain to domestic consumers. Most of the gains to increased tick control will go domestic producers.[14]

In the dairy industry a number of pricing structures exist. For some products, particularly fluid milk, the domestic price is regulated. As pointed out by Freebairn [15] for these products it might be suggested superficially that domestic consumers would gain very little and producers most of the benefits arising from maximal control or eradication of cattle ticks in New South Wales so far as they affect dairy cattle. But as Freebairn notes also in the bargaining process of arriving at regulated domestic dairy product prices it is likely some consideration is given to production costs. If this is so, policy decisions to increase the use

[14] This assumption that the change in producer surplus will be positive will depend, as pointed out by Duncan and Tisdell [9, p. 126], on demand being highly elastic and the reduction of costs to producers at the margin being equal to or less than the reduction for inframarginal producers.

of resources for the control of cattle ticks should reduce the domestic price to consumers and vice versa. For this structure consumers would reap most of the benefits of increased control and given the inelastic demand curve for fluid milk, producers may lose in terms of a fall in gross receipts and quasi rents.

For other dairy products in which the demand curve is primarily export determined and highly elastic producers would reap most of the gains and domestic consumers very little of the gains from greater tick control.

A high proportion of cattle hides produced in Australia, both clean[15] and ticky[16], are exported. The elasticity of demand for hides is therefore most probably high. The price differential between clean and ticky hides is also substantial.[17] Any reduction of control in New South Wales which results in the production of ticky hides would reduce surplus to hide producers but would have little effect on hide consumers.

The above analysis reveals that domestic and overseas consumers of all beef and dairy products except those for which price is regulated together with consumers of hides would not be significantly affected by a change in government policy on cattle ticks in New South Wales either to eradication or to some policy of reduced control. Producers on the other hand within the area of potential tick distribution (APTD) benefit significantly from cattle tick control and by inference would lose significantly from reduced benefits of tick control if control were reduced in New South Wales.

A significant difference is evident between the present policy of financing tick control in New South Wales from consolidated revenue funds and a "desirable" policy in which the beneficiaries of tick control would pay for control. The cost of control should be borne by beef and dairy producers within the APTD and consumers in proportion to the amount by which they benefit.[18] This is desirable for reasons of both equity and economic efficiency. From the above consumers should bear little or none of the cost. Charges should be imposed on beef and dairy producers outside the T.Q.A. but within the APTD as well as producers within the T.Q.A. who suffer some private costs of mustering cattle for dipping, marketing costs, etc. associated with tick control. Producers outside the T.Q.A. bear no such costs.[19]

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[15] Over the period 1970–1 to 1973–4 Australian exports of bovine hides averaged 85 per cent by weight of estimated domestic production based upon slaughterings and ranged from 73 per cent in 1971–2 to 101 per cent in 1973–4.

[16] A submission to the Committee of Enquiry [6] from the Queensland Department of Primary Industry indicated most ticky hides from Queensland are exported.

[17] A submission to the Committee of Enquiry [6] indicated the discount made on ticky hides to be approximately 20 to 30 per cent of the value of clean hides.

[18] Recommendation for adjustments in the financing of control in New South Wales are not particularly original. Mackerras *et al.* [18] as a Committee of Enquiry into the N.S.W. Government Cattle Tick policy in 1961 recommended the transfer of costs of control from Government to stock owners.

[19] As Davies [8] noted "if stockowners (in the T.Q.A.) are protecting the rest of the State then the stockowners in the rest of the State have no moral case for refusing to contribute to the cost of control".

How then should taxes be levied in order to raise finance for tick control?

Given perfect competition and if a tax is imposed on beef, or dairy products or hides, then the incidence of this tax on producers and consumers of these products will be in proportion to the extent they benefit from a shift in supply to the right. Lack of perfect competition in the form of higher bargaining power held by processors, agents and other intermediaries in the markets for these products compared with cattle owners may mean that producers would bear the full cost of any tax imposed at the producer or wholesale level. However, given the small extent to which consumers benefit from tick control this would not result in a serious misallocation of resources. Some sort of stamp duty on hides, beef and dairy products or an addition to Pastures Protection (P.P.) Board rates on all cattle would therefore seem a desirable way of raising finance.

On the question of what should be the geographic incidence of a tax a distinction should be made between the different types of costs. The principal distinction will be between individual control inputs such as policy dipping (control activities having restricted external benefit mainly of the "ownership" type) and common tick control inputs such as research, extension, maintenance of buffer zones, etc. (control activities providing major ownership or public good externalities). So far as possible stock owners should be charged according to the amount of individual tick control inputs they receive. On this basis each stock owner should be charged a higher proportion of the cost of policy dippings than of movement dippings (on the assumption that external benefits provided by policy dippings are less than those provided by movement dippings).

So far as the financing of common control inputs is concerned the benefits of these will vary geographically throughout the APTD according to the ecological suitability of the property location, the proximity of the area to the T.Q.A. and possibly the enterprise type. For farms within the T.Q.A. the more ecologically favourable the farm location and enterprise type then the higher will be the costs of control. For farms within the APTD but outside the T.Q.A., the more ecologically favourable the area and the closer its proximity to the T.Q.A. the higher the probability of infestations of previously clean areas; the greater the likely loss from tick worry and tick fever in these areas; and therefore the greater the expected benefit conferred by quarantine measures and tick control within the T.Q.A[20].

[20] An unequal distribution of the costs of cattle tick control within the APTD is not only desirable on economic efficiency grounds but also on equity grounds. Producers within and outside the T.Q.A. do not benefit equally from each dollar expended on tick control. A beef producer in the Murrumbidgee Irrigation Area will not benefit to anywhere near the same extent as a beef producer at Coffs Harbour just south of the T.Q.A. or another producer at Casino well within the T.Q.A. Similarly each producer will not benefit equally from a dollar spent in various ways on tick control. A dollar spent on dipping cattle prior to movement outside the T.Q.A. to a Coffs Harbour cattle owner would be of far greater value to another Coffs Harbour cattle owner than a dollar spent on policy dipping at Casino. Taxes imposed upon producers within the APTD should reflect these differences.

The costs of common control inputs could be distributed within the APTD on the basis of an index of expected annual benefits conferred on various control inputs in different areas. Such an index could be calculated using some appropriate formula determined by biological and economic research. Subjective estimates could be obtained for the independent variables in such a formula from entomologists, veterinarians and other biologists concerned with cattle tick research and control administration. These variables would include the likelihood of ticks being transported to a certain area; the likelihood of a population being established given transportation of ticks to that area; the likelihood of ticks in an area completing a certain number of generations; of these ticks carrying tick fever; relative estimates of the losses which would result from tick worry and tick fever given certain number or numbers of populations of ticks in a season; and so on.

Location would seem to be the most important factor in influencing the likely benefits. An addition to PP Board rates per beast for districts within the APTD would therefore seem the simplest administrative method of raising finance. Estimates of expected annual benefits would be made for each PP Board district. If enterprise type (beef or dairy) was also considered to be an important factor determining expected annual benefits then a distinction could be made on cattle type in PP Board rates. If collection of an added levy through PP Boards was not possible then investigation of some alternative means of collecting finance on a per property basis would be desirable. Stamp duties on beef and dairy products could be used to distinguish between enterprise types but they could not be used to levy areas differently.

5 SELECTION OF THE BEST POLICY

This section considers the question of how alternative strategies for cattle tick control should be evaluated. It describes a cost benefit study by Johnston and Mason [16] which aimed at selecting the best tick control strategy for New South Wales from a limited number of alternatives. It goes on to discuss the shortcomings of this study and the need for further comprehensive studies of cattle tick policy in New South Wales. As noted previously several continuous factor-product functions can be thought to exist relating savings in hides, beef and dairy production to tick control inputs. Existence of such a set of relationships implies the existence of an infinite array of control strategies each of which will involve a combination of the available control methods. In the absence of government intervention private decision-making can be thought of as involving a choice of the best strategy from this infinite array.

For government decision-making further dimensions must be added to the decision model to include policy instruments and their impact on the partial relationships between private production savings and control inputs.[21] Given the prices of products saved and of control policy inputs, simultaneous determination of both the optimal strategy and combination of policy instruments would be theoretically possible.

[21] Care should be taken to include intangible as well as tangible benefits and costs of control and the transactions costs of the various policy instruments. Failure to include intangible benefits and costs has received much attention in the benefit-cost literature and will not be dwelt upon here. (*See* Mishan [22] and Lave [17].)

Selection of the best policy will inevitably involve simplification of this decision problem down to consideration of a small number of strategies and policy instruments.

5.1 THE STUDY

As with most studies of government policy on disease and pest control the study by Johnston and Mason [16] assumed the wisdom of government involvement at a certain level.[22]

The study was an evaluation of present control measures compared with eradication in respect of New South Wales. It assumed that the New South Wales Government will continue to pay for tick control and that the expenses of land holders in the T.Q.A. will be confined to the cost of mustering cattle for dipping or inspection and the added marketing costs imposed by quarantine regulations.

Two basic comparisons were made:

(i) between continuation of the present policy of control (referred to as Control) and two so-called "eradication" policies (referred to as eradication A and B) involving intensified control in the short term leading to a reduction of the cost of control measures in the long term.

(ii) between two types of quarantine buffers on the Queensland border combined with the above policies—the present 5-chain buffer and a '5-mile' buffer.

Technically the control policy is aimed at keeping ticks to their present low population in New South Wales. The eradication policies are aimed at eradicating resident ticks and dealing with reinfestations from Queensland on a spot eradication basis as they occur.

Eradication B was included as a technically more conservative policy and involved maintenance of quarantine boundaries of the T.Q.A. following eradication. As such it was a more expensive policy. A quarantine buffer zone is a fenced strip on a quarantine boundary from which cattle are excluded or else in which cattle are dipped intensively. Such buffers reduce the likelihood of ticks moving on the ground or on hosts across the quarantine boundary.[23]

5.1.1 Methodology

The alternative policies were compared on the basis of present discounted cost using basically the standard methodology of cost-benefit analysis. The benefits of tick control and eradication—avoidance of production losses—were assumed to be quantitatively the same. This was done on the grounds that, over the relevant planning horizon, control and

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[22] See Power and Harris [29] and Ellis [11].

[23] The study did not consider technical variations in eradication strategy by the search and destroy approach. As noted by the Committee of Enquiry on the Cattle Tick [6, pp. 32–33] in reference to Johnston and Mason [16], a reduced frequency of inspection and time taken to inspect each beast could be expected to considerably reduce the cost of eradication from our calculations.

eradication will probably be equally effective in keeping tick numbers, and therefore production losses, to a negligible level. Policies were therefore compared on the basis of their present discounted cost.[24] The methodology differed from that used in many other cost-benefit analyses in the treatment of uncertainty.

(a) *Costs of Tick Control versus Eradication*

Estimates were made for each policy of the stream of costs for each year over the planning horizon by calculating the values of these costs in 1973–4 (year 1) and then projecting them into the future. Allowance was made in these projections for a 3 per cent annual increase in cattle numbers over the 1972–3 population. This was based on an assessment of the past growth in cattle numbers in Richmond–Tweed and Clarence Statistical Subdivisions (which include most of the T.Q.A., and the assumption that this growth would continue given low but increasing levels of pasture improvement and good market prospects for beef at the time of the study).

Costs were divided into those borne by the Board of Tick Control (Public Costs) and those borne by individual property owners, agents in the sale of livestock or drivers of vehicles stopped at quarantine gates (Private Costs). Table 1 sets out the categories of costs considered. For most of these costs single-valued estimates were derived, in most cases the median. In the case of infestations, various possible numbers of infestations were considered and an expected cost of infestations was derived for each year and area. For this reason the table is broken up into those costs assumed certain and those uncertain. The treatment of uncertainty is considered later.

Because of the difficulty which would be involved in estimating the private costs of quarantine boundaries in terms of profits foregone from trade which does not take place, these were not accounted for. These profits foregone would largely be restricted to forestry operations and are not considered to be great compared with the other private costs estimated.

(b) *Discount Rates and Planning Horizon*

The analysis was made using four discount rates—3, 5, 7 and 9 per cent. Five planning horizons were used—20, 30, 40, 50 and an infinite number of years. The use of a discount rate by policymakers within the range 7 to 9 per cent was advocated based on an opportunity cost rate. The long-term bond rate of approximately 7 per cent at that time was taken as a minimum and no discount for risk was assumed following the arguments of Arrow [1].

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[24] That is to say, the costs associated with a policy in each year over the planning horizon were discounted according to a particular interest rate and summed to give a present cost. This was repeated for each of the interest rates and planning horizons in the ranges of these considered.

TABLE 1

Categories of Costs Assessed in the Comparison of Control and Eradication

Public Costs (Board of Tick Control)	
(*i*) *Costs assumed certain*	
Staff—required to undertake all specified policy except the treatment of infestations.	
Acaricides—for dipping other than on infested and adjoining holding.	
Repairs and Maintenance	
Replacement Capital New Capital Items	Allocated to the years when replacement or new capital expenditure would be necessary.
Travelling Compensation for Dipping Losses Leasing of Unmusterable Country	Other than on infested and adjoining holdings.
Other General Stores and Equipment	
(ii) *Costs assumed uncertain*	
Infestations—includes costs of staff, acaricides, travelling, leasing and compensation.	
Private Costs	
(i) *Costs assumed certain*	
Labour—for treatments specified by policy other than on infested and adjoining holdings.	
Marketing Costs—the cost of holding cattle for treatment for movement to clean country.	
Cost to motorists and transporters of stopping at quarantine boundary gates.	
(ii) *Costs assumed uncertain*	
Infestations—the cost of private labour associated with the treatment of infestations	

(*c*) *Treatment of Uncetainty*

Uncertainty surrounds the efficiency which can be expected of the alternative policies in achieving the desired objectives. A limited attempt was made to assess the impact of uncertainty on the present discounted cost of control and eradication.

Various approaches have been taken to uncertainty in public project analysis, the traditional being sensitivity analysis. It was intended in this study to use a probabilistic approach of the type advocated by Reutlinger [32] and used by Cassidy *et al.* [5] in which subjective probability distribution would be estimated for important variables and a probability distributions generated for present discounted cost using simulation [23]. Much of the data was collected on this basis. Time did not allow the use of simulation but subjective probability distributions were estimated for two important variables. The impact of uncertainty in other variables on the results was considered by sensitivity analysis. The uncertain variables were:

(i) the number of tick infestations likely to be found in each area of the T.Q.A. under various policies and requiring spot eradication.

(ii) the number of years likely to be taken to achieve eradication in any area within the T.Q.A.—the assumed test of an eradicated area being two years without an infestation.

Probability distributions for each of these were estimated by a technical panel of veterinarians and research personnel involved in administration of and research on tick control. Approximately 120 discrete distributions were estimated using ludo counters in the manner described by Francisco and Anderson [14]. The panel did not have difficulty in either understanding probability distributions or making estimates. They were aided in their deliberations by historical information on numbers of infestations in each region. Two observations are perhaps valuable:

(i) members of the panel, after completion of the job, thought they should "play the game" more often to force themselves to quantify their relative confidence in alternative policies which they recommended to policymakers;

(ii) the policymakers in the form of the Committee of Enquiry to whom the report was presented, seemed satisfied with the estimation of subjective probability distributions by a group other than themselves.

Probability distributions for the number of infestations per year were applied to the cost of infestation for a range of values of the variable to calculate expected public and private costs of infestations for each year. These were added to the total of all other public and private costs, by years, before discounting.

Probability distributions for the number of years likely to be taken to achieve eradication were applied to the present discounted cost of eradication A and B for a range of values of the variable to obtain an expected present discounted cost of these policies.

(d) *Sources of Data*

Much of the data, most importantly those on staff requirement estimates, were obtained from a detailed questionnaire and personal interviews with the inspectors in charge of all nine regions within the T.Q.A. All estimates of median values of labour requirements per infestation, both public and private, acaricide costs, leasing costs, cattle numbers per infestation and others were based on adequate numbers of sample observations (more than 30) and hand smoothing of cumulative frequency curves to assess quartiles of the distribution. However only the medians were used. Much of the data were provided by the Chairman and Deputy Chairman, Board of Tick Control from headquarter's records.

5.1.2. RESULTS OF THE STUDY

(a) *Annual Costs*

Table 2 sets out in summary the annual costs anticipated for Control and eradication A and B based on present cost levels and cattle numbers. Annual costs are given for before and after eradication in the case of eradication A and B.[25]

[25] Details of these costs and of the methods used in deriving them may be found in appendices to Johnston and Mason [16].

In Control annual expected costs (public plus private) would amount to $4.21 million with the present buffer. The eradication policies would result in total annual expected costs of $7·18 million prior to eradication and following eradication this would fall to $1·8 million for eradication A and $2·57 million for eradication B—for the present buffer. A 5-mile buffer would increase all these costs by between $0·87 million and $0·89 million per annum.

TABLE 2

The Estimated Annual Costs of the Alternative Policies, Control, Eradication A and Eradication B

Policy	Annual Costs	
Control—	$m	
Present Buffer—Public Costs	3.60	
—Private Costs	0.61	
	4.21	
5-mile Buffer—Public Costs	4.48	
—Private Costs	0.76	
	5.24	
	Before eradication	After eradication
Eradication A—	$m	$m
Present Buffer—Public Costs	6.23	1.64
—Private Costs	0.94	0.16
	7.18	1.80
5-mile Buffer—Public Costs	6.80	2.35
—Private Costs	1.24	0.34
	8.05	2.69
Eradication B—		
Present Buffer—Public Costs	6.23	2.28
—Private Costs	0.94	0.29
	7.18	2.57
5-mile Buffer—Public Costs	6.80	2.99
—Private Costs	1.24	0.46
	8.05	3.45

NOTES:

(a) Errors in addition are due to rounding. The analysis was conducted with an order of accuracy to the nearest $1,000.

(b) Bowraville and Kempsey Quarantine Areas have been excluded from consideration as has the cost of Cattle Tick Research conducted by the New South Wales Department of Agriculture.

(c) Estimates are based on present cattle numbers and costs (1972–3 base).

b) *The Comparison of Control and Eradication*

The present discounted cost of Control and the expected present discounted cost of eradication A and B with the present buffer are shown in table 3 and figure 4 for an infinite planning horizon. [26]The sensitivity of the present cost of eradication to variations in the time taken to achieve eradication was assessed by calculating an optimistic and a pessimistic cost based on the expectations of the technical panel. These values, contained in Table 4 and shown graphically in figures 5 and 6 for eradication A and B compared with Control, represent crude 10 per cent confidence limits calculated about the curve of expected eradication costs. Such a presentation of the results seemed to be readily comprehended by the non-economist policymakers to whom the report was presented.

TABLE 3

The Present Discounted Cost of Control and the Expected Present Discounted Cost of Eradication A and B—of the Cattle Tick in N.S.W.—with the Present Buffer on the Queensland Border

	Discount Rates per cent			
	3	5	7	9
Control—	$m	$m	$m	$m
Public	155	91	64	49
Private	26	15	11	8
	181	106	75	57
Eradication A—				
Public	100	69	55	47
Private	13	10	8	7
	113	79	64	54
Eradication B—				
Public	115	77	60	50
Private	18	13	10	8
	134	90	71	59

NOTES:

(a) Errors in addition are due to rounding. The analysis was conducted with an order of accuracy to the nearest $1,000.

(b) Bowraville and Kempsey Quarantine Areas have been excluded from consideration as has the cost of Cattle Tick Research conducted by the New South Wales Department of Agriculture.

[26] Figures 4, 5, 6, and 7 are contained in Appendix A.

TABLE 4

Present Discounted Cost of Eradication A and B for an Optimistic versus a Pessimistic View of the Time Likely to be Taken to Achieve Eradication—with the Present Buffer

	Discount Rates per cent			
	3	5	7	9
Eradication A—				
(i) Minimum—				
Public Costs	89·4	60·1	47·0	39·4
Private Costs	10·8	8·0	6·7	5·8
	100·2	68·1	53·7	45·2
(ii) Maximum—				
Public Costs	107·7	77·7	62·2	52·5
Private Costs	14·9	11·6	9·7	8·4
	122·6	89·3	71·8	60·9
Eradication B—				
(i) Minimum—				
Public Costs	105·3	68·8	52·8	43·6
Private Costs	15·6	10·6	8·3	7·0
	120·9	79·5	61·1	50·6
(ii) Maximum—				
Public Costs	121·8	84·9	66·7	56·6
Private Costs	19·1	13·7	11·1	9·2
	141·0	98·6	77·7	65·8

NOTES:

(a) Errors in addition are due to rounding. The analysis was conducted with an order of accuracy to the nearest $1,000.

(b) Bowraville and Kempsey Quarantine Areas have been excluded from consideration as has the cost of Cattle Tick Research conducted by the New South Wales Department of Agriculture.

From the curves of the type in figures 4, 5 and 6, break even discount rates were plotted against planning horizon to produce break even curves as shown in figure 7. These show either the discount rate at which policy-makers would be indifferent between Control and eradication for a selected planning horizon or, alternatively, the minimum period in which the long-run savings could outway the short-term costs of eradication compared with Control at a selected discount rate. This discount rate/planning horizon break even analysis is also shown in table 5.

TABLE 5

Minimum Planning Horizon for Eradication A to be Superior to Control or alternatively the Pay-back period for Eradication A over Control

Discount Rate per cent	Type of Expectation on the Time Required to Achieve Eradication		
	Optimistic	Average	Pessimistic
	(years)	(years)	(years)
6	14	22	34
7	15	23	40
8	16	26	inferior
9	17	30	inferior

These curves summarize the comparison of the alternative policies in terms of the two decision variables; the discount rate and the planning horizon. The methodology of cost-benefit analysis requires that values for these variables should be selected by the decision-maker. But based on acceptance of the expectations of the technical panel, the advocated discount rate of 7 per cent to 9 per cent and a planning horizon of 30 years or more, the following conclusions were drawn.

A policy of eradication involving property inspection and spot eradication, followed by declaration of eradication and dismantling of quarantine boundaries would, most probably, be less expensive in the long run than continuing control. If however, external quarantine boundaries were maintained indefinitely following declaration of eradication, it is difficult to say which would be the cheaper policy.

It was found unlikely that a 5-mile buffer would be beneficial, on economic grounds, in comparison with the present buffer.

The value of a buffer depends on the number of infestations it prevents and in this case savings in spot eradication costs due to the 5-mile buffer would not exceed its cost.

5.2 FUTURE POLICY EVALUATION

The study did not consider strategies of reduced control with the use of *Bos indicus* cattle nor the use of alternative policy instruments such as producer education and various forms of input and output subsidies. There is good reason to believe, as is argued in the following paragraphs, that some of these alternative policies could be better than the policies considered in the study. They therefore deserve further consideration.

No economic valuations of the losses likely to result from reduced control of ticks in New South Wales have been made since Mackerras *et al.* [18] made estimates based upon assumptions concerning tick distribution which have been subsequently proved incorrect.[27] In addition the

[27] *See* McCulloch and Lewis [20].

development of tick fever vaccine and the availability of tick resistant cattle has undoubtedly weakened the case for eradication in New South Wales.

The intensive control programme currently operating in New South Wales would not appear to be a viable long-term policy. The cost of this programme is likely to increase, relative to other methods of control for two reasons. Firstly, dipping relative to the use of tick resistant cattle, is a labour intensive form of control. Labour costs will probably increase at a greater rate than beef prices. Without radical labour-saving improvements in dipping procedures, the ratio of benefits to costs of tick control will diminish. Secondly, the cost of dipping is also likely to increase relative to the cost of other control measures because of the increasing cost of developing new acaricides at a faster rate than the rate of development of resistance to acaricides by ticks. Even if the rate of development of resistance were constant, the cost of research and development of efficient acaricides is likely to increase because of the nature of research and development on new acaricides. The discovery of new chemical groups suitable as acaricides is essentially a random process of screening.[28] Since the supply of known toxic chemical groups with potential as conventional acaricides in small and fairly static then the success rate in this screening process is probably diminishing with a resultant increase in research and development costs.[29]

If eradication is attempted and fails or is judged to be infeasible or uneconomic, some reduced form of control is likely to be optimal in the long run with a greater use of tick resistant cattle relative to dipping.

6 Conclusions

The New South Wales Government has become heavily involved in the control of cattle ticks. While an analysis of the free market allocation of resources to tick control revealed strong justification for government intervention, doubts were raised about the optimality of the present policy. The level of control adopted could well be too intense and even if optimal at present is unlikely to remain so unless eradication proves feasible. Some policy instruments such as the extension of information seem under utilized and the present system of financing cattle tick control is economically inefficient and inequitable.

Further theoretical and empirical research to examine alternative control strategies would be desirable. Since the economic characteristics of cattle ticks and their control are similar to other diseases and pests, this research could also assist in the allocation of public and private funds to the control of other agricultural pests and diseases.

Government involvement in cattle tick control is justified to overcome market failure caused by significant externalities, risk and economies of scale in cattle tick control and ignorance of control methods by producers.

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[28] Denham, D., "Ticks Future Limited", *The Land* newspaper, 15.2.1973.

[29] New innovations in chemical control, specifically to overcome the organophosphate resistance problem are likely to have a fraction of the present world market for acaricides [37].

The choice of an optimal strategy involves simultaneous determination of the types and intensity of control and the policy instruments to be used to achieve a better allocation of resources.

In considering the distribution of benefits it was shown that cattle owners gain most from tick control and will therefore stand to gain or lose most from changes in cattle tick control policy in New South Wales. Consumers of hides, beef and dairy products, both here and overseas, are little affected. It was argued that all cattle owners within the area of potential tick distribution should be levied to finance tick control according to the degree to which they benefit from control and the control costs they pay privately. This will largely depend upon their location and also possibly the type of enterprise; whether beef or dairying. The collection of levies for tick control through P.P. Board rates was advocated.

The benefit cost evaluation of alternative policies for cattle ticks in New South Wales was restricted to comparing policies of intensive control or eradication. It was shown that eradication on certain assumptions, would, most probably, be superior to control in the long term.

The study employed techniques of explicitly treating uncertainty which could be useful in other economic studies of disease and pest control. It provides an example of the empirical estimation of subjective probability distributions by research personnel and administrators in a group decision situation. These people seemed to have no great difficulty in estimating these functions or in reaching a consensus.

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APPENDIX "A"

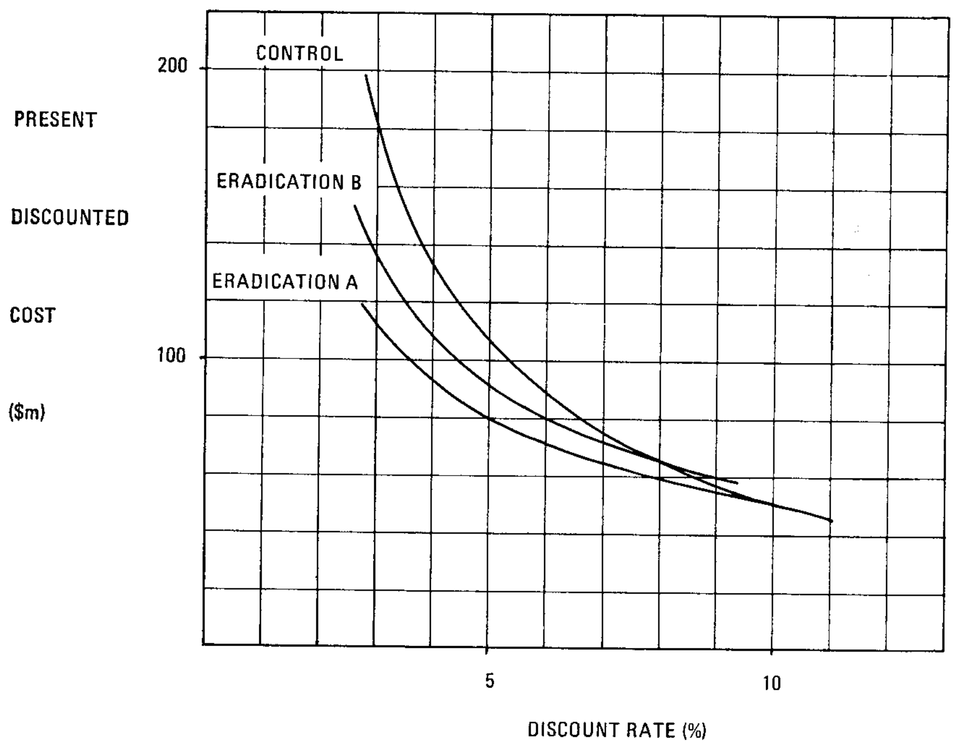

FIGURE 4—*The Present Discounted cost of Control compared with eradication A and B —present buffer*

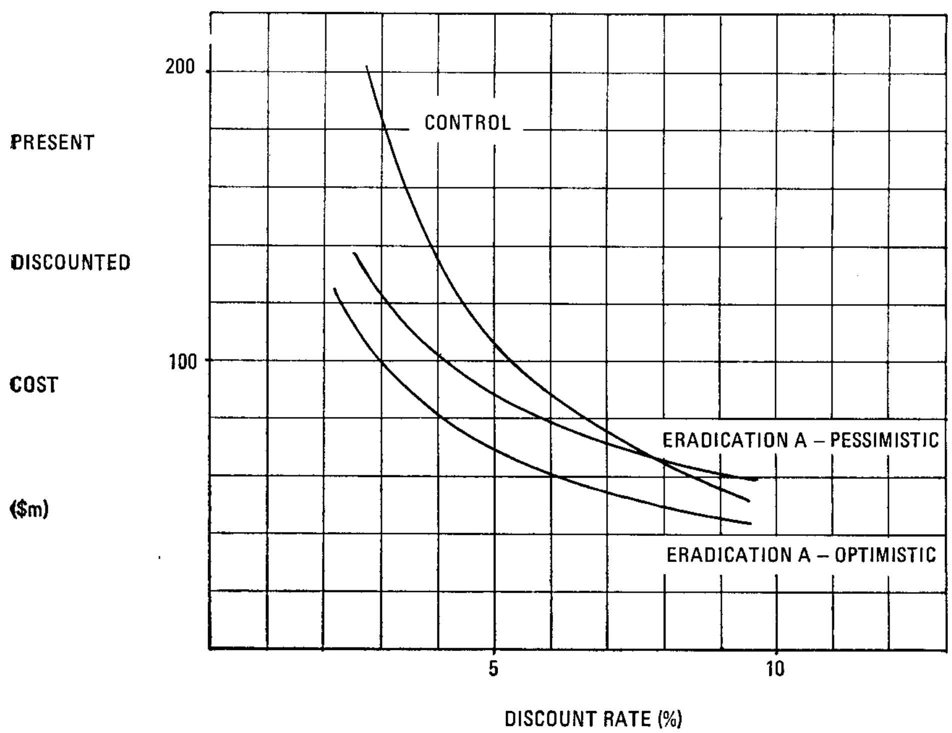

FIGURE 5—*Eradication A—expected present discounted cost on optimistic and pessimistic assessments of the required to achieve eradication*

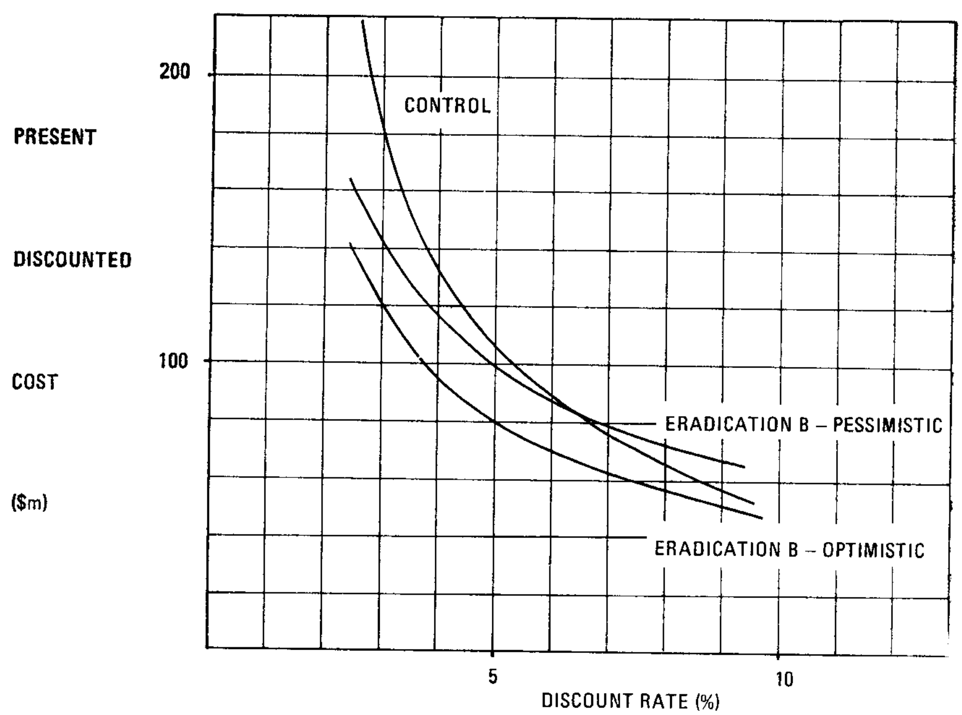

FIGURE 6—*Eradication B—expected discounted costs on optimistic and pessimistic assessments of the time required to achieve eradication*

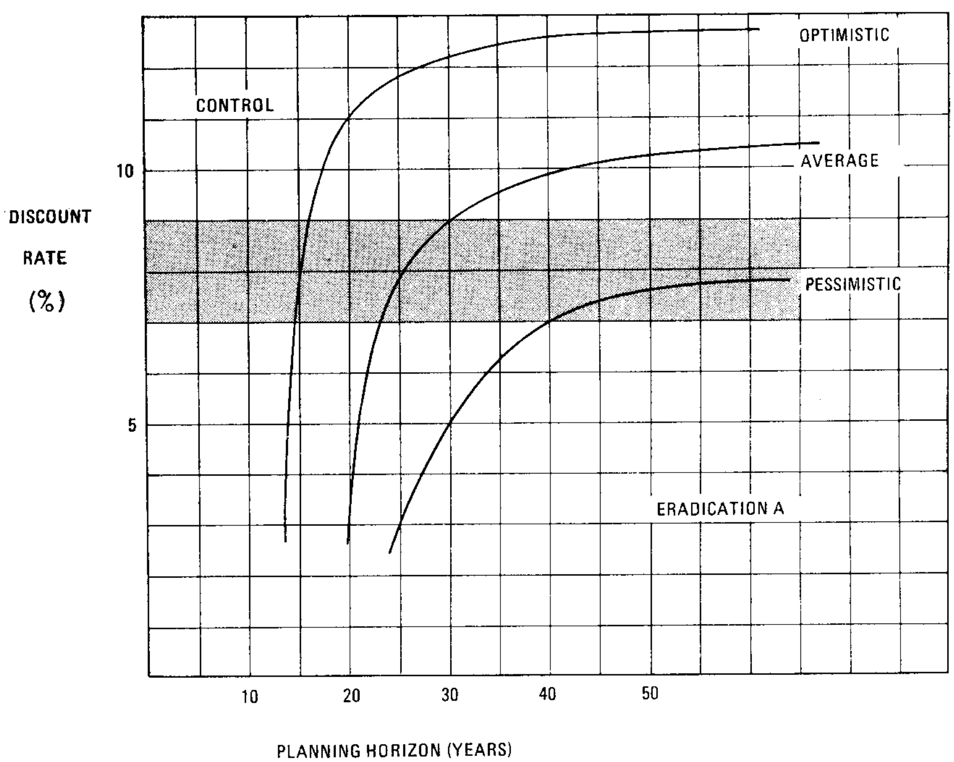

FIGURE 7—*Break-even curves for eradication A compared with Control-based on average, optimistic and pessimistic expectations of the time required to achieve eradication*