DYNAMICS OF HERD BUILDUP IN

COMMERCIAL DEER PRODUCTION

R.A. Sandrey

and

A.C. Zwart

RESEARCH REPORT NO. 153

MAY 1984

Agricultural Economics Research Unit
Lincoln College
Canterbury

ISSN 0069-3790

THE AGRICULTURAL ECONOMICS RESEARCH UNIT
Lincoln College, Canterbury, N.Z.

The Agricultural Economics Research Unit (AERU) was established in 1962 at Lincoln College, University of Canterbury. The aims of the Unit are to assist by way of economic research those groups involved in the many aspects of New Zealand primary production and product processing, distribution and marketing.

Major sources of funding have been annual grants from the Department of Scientific and Industrial Research and the College. However, a substantial proportion of the Unit's budget is derived from specific project research under contract to government departments, producer boards, farmer organisations and to commercial and industrial groups.

The Unit is involved in a wide spectrum of agricultural economics and management research, with some concentration on production economics, natural resource economics, marketing, processing and transportation. The results of research projects are published as Research Reports or Discussion Papers. (For further information regarding the Unit's publications see the inside back cover). The Unit also sponsors periodic conferences and seminars on topics of regional and national interest, often in conjunction with other organisations.

The Unit is guided in policy formation by an Advisory Committee first established in 1982.

The AERU, the Department of Agricultural Economics and Marketing, and the Department of Farm Management and Rural Valuation maintain a close working relationship on research and associated matters. The heads of these two Departments are represented on the Advisory Committee, and together with the Director, constitute an AERU Policy Committee.

CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

PREFACE

The study described in this report is valuable in that it explains, in economic terms, the high prices currently being paid for live deer in New Zealand. While there continues to be uncertainty associated with deer velvet prices, the existence of a model such as described in this report is useful to explore the effects that different assumptions on velvet prices (and venison prices) may have on deer prices, slaughter throughputs and venison exports.

The study and report were completed by R.A. Sandrey and A.C. Zwart (Lecturer and Senior Lecturer respectively, in the Department of Agricultural Economics and Marketing at the College). An earlier version of this paper was presented at the Conference of the Australian Agricultural Economics Society held in Sydney in February, 1984.

P.D. Chudleigh
Director

ACKNOWLEDGEMENTS

The authors are grateful for constructive comments received from R.G. Lattimore. Financial support for this research was received from the Game Export Advisory Committee, a sub-committee of the New Zealand Deer Farmers Association.

CHAPTER 1

INTRODUCTION

Substantial changes have occurred to the status of New Zealand's red deer population in the last 20 years. During this period the deer has progressed from being a noxious animal to becoming the basis of a new glamour livestock industry. The late 1970s saw a change in emphasis from feral venison slaughter to the recovery of hinds to start the present farmed industry, an industry which was illegal prior to 1969. Although the animal must be viewed as a dual purpose animal capable of producing both velvet (antlers) and venison, concern is being expressed within the industry that insufficient supplies of farmed venison are available to maintain and develop what appear to be promising new markets. The low level of venison supply is caused by:

(1) the current demand for hinds (females) creating a market price above the slaughter value; and

(2) velvet returns at present are such that stags (males) are being retained for velvet production.

It would appear that this situation merely reflects the dynamics that would be associated with the rapid build up of numbers in any livestock industry. There is some cause for concern, however, in the information which producers are utilising in making decisions about expected returns from venison and velvet production. For example, prices for breeding stock which are being retained as a part of the rapid herd build-up are presently based on a relatively small volume of output and in an uncertain market environment.

This paper attempts to provide information about the adjustment process by examining the decision rules facing producers deciding whether to slaughter or retain animals. The study also estimates some likely medium term venison and velvet production figures under alternative price assumptions.

The decision rules are derived by formulating the producers' problem in a capital decision making model. A computer simulation model of the national herd structure is also developed, and these two models are integrated to develop some possible production and growth paths for the industry in the medium term.

While these issues would normally be handled in an econometric analysis, the lack of historical information has led to the use of a methodology which utilises normative models as the basis for projections.

CHAPTER 2

NEW ZEALAND DEER INDUSTRY

2.1 Introduction

Deer[1] were introduced into New Zealand late last century, and herd sizes increased to the extent that feral (wild) deer were declared noxious animals. These numbers stayed high in spite of culling pressure until the development of an export venison industry in the mid 1960s.

In 1969, commercial deer farming was officially sanctioned and the demand for live deer for breeding placed an additional "pull" on stock of feral deer - this time for live capture. The successful development of commercial deer farming technological packages and continued high expected prices for velvet (from antlers of males) resulted in continuing high prices[2] for live deer (their capital price) relative to their meat value, particularly for females (hinds). Currently (April 1984) mixed age hinds are being sold forward for \$2,000-\$2,200, yearling hinds for \$1,750 and weaner hinds for \$1,500. At the same time mixed age stags are fetching \$250-\$400. The slaughter value of mixed age animals is around \$250-\$450.

2.2 Venison

As commercial deer farming developed over the seventies, the cost of capturing feral deer started to rise[3], as feral stocks were being depleted. Venison supplies from feral deer were diminishing because the payoff to live deer capture was significantly higher than their meat value given the demands of commercial operations for breeding stock. Venison processors and exporters continued to operate in the

---

1. Red deer are the predominant species, with some fallow, sika, and wapiti locally important.
2. 'High' relative to other competing farm products and relative to venison returns on slaughter.
3. Measuring costs as thousands of deer recovered per helicopter year of effective operation enabled the following equation to be fitted for carcass recovery:

$$Y = 14.41e^{-0.1505X} \qquad r^2 = 0.93$$

where: Y = deer (x 10^3)/helicopter year,
and X = time series, 1966 = 1 to 1977 = 12.

expectation that feral supplies would be replaced by supplies of cull animals from commercial farms. To date this has not occurred to a significant degree, and hence the concern by industry planners and the processing industry that

> "Because of low throughput, development of the industry is being damaged through inability to supply product to new markets in a regular and orderly manner. ... animals with less desirable characteristics ... be culled now providing the much needed throughput. ... farmers should request livestock companies to substantiate the current high live animal prices on the basis of realistic velvet, meat and by-product prices." (NZDFA, 1983).

The killing of farmed deer is carried out in Deer Slaughter Premises, while Game Packing Houses undertake feral carcass processing. The degree of excess capacity in the Deer Slaughter Premises is evident when it is considered that some 700 tonnes of farm deer were processed in 1982/83, while the industry has a capacity to process an estimated 35 tonnes of farmed venison per day (Bank of New Zealand, 1983).

Exports of feral venison packed in 1972 at 4,386 tonnes - almost three times the 1983 export of both feral and farmed venison combined. Returns in real terms per animal peaked in 1977 (Figure 1), the same year that nominal exports reached a high of 11.86 million dollars. Prices of feral animals, expressed in 1965 dollars have trended upwards until 1977 and have weakened slightly in subsequent years. These prices are shown on Figure 1, with an estimated average weight of 33kg per carcass[4]. Meantime, production and exports of the more lucrative velvet continues to grow, principally from commercial farms.

2.3 Velvet

Real prices for velvet peaked in 1979 and then dropped dramatically. Since then prices have remained relatively constant. Prices for Super A grade velvet are shown in Figure 2, for the years 1976-77 to the present 1983-84 season.

Currently (April 1984) considerable uncertainty exists in the velvet market. Supplies are being held by processors in New Zealand as the Korean market is closed pending investigations of trading practices within that country. The importance of the Korean market to New Zealand velvet producers can be seen in Table 1. For the year ending June 1983 some 59 per cent (by value) of New Zealand velvet exports were to Korea, much in processed form.

---

4. Pers. comm., Dr Chris Challies, New Zealand Forest Service.

Figure 1. Index of Returns per feral deer carcass (1965 $)

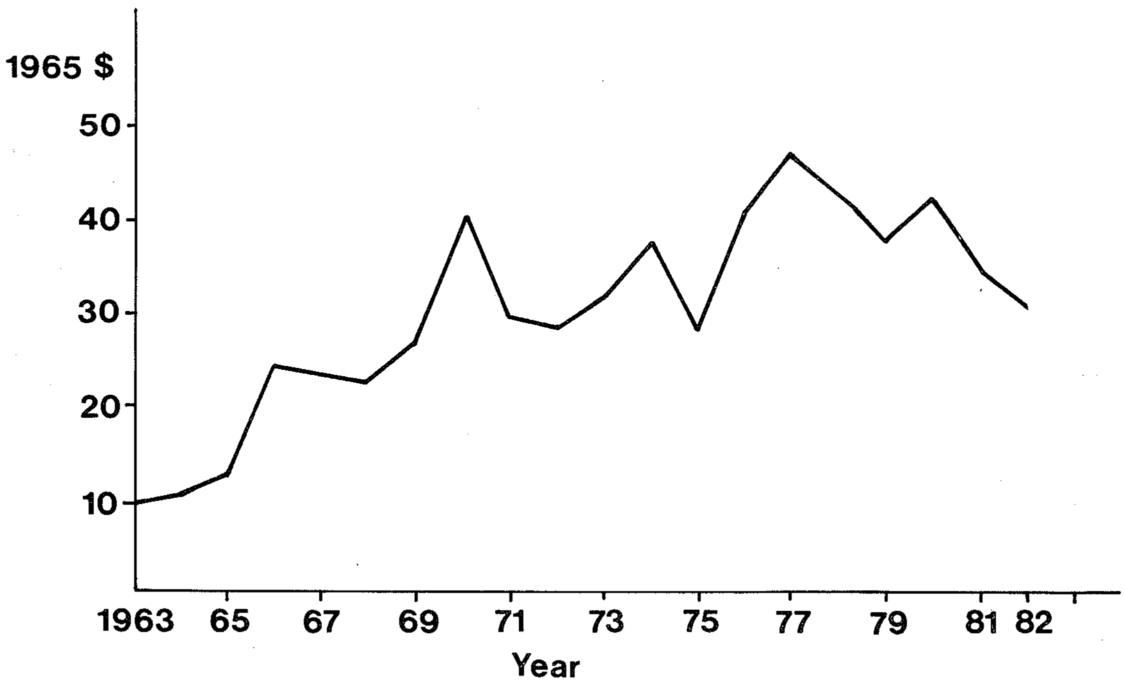


TABLE 1

Exports Of New Zealand Velvet
Year Ending June 1983, Values f.o.b.

	Kg	$000	Per Cent	$/kg
Korea	5,300	2,356	59	445
Taiwan	3,811	435	11	114
Hong Kong	2,814	677	17	241
U.S.A.	2,526	247	6	98
Japan	630	250	6	297
Other	25	13	1	520
Total	15,106	3,978	100	

SOURCE: Bank of New Zealand.

Velvet production has been steadily increasing over the last few years, as shown in Table 2. This production has the potential to expand rapidly over the next few seasons, as male animals may be held back from slaughter to produce velvet. Effects of this can be shown by looking at the response function of velvet production with respect to age, Table 3. Although some velvet is harvested in the early years of the animal's life, this is mainly low quality velvet. Grading appears to be subjective, but weight is undoubtedly important, thus a high return cannot be expected under the current pricing regime until the animal is 5 or 6 years old.

Care must be taken in interpreting Table 2, as some carryover effects from one year to the next may be distorting trends. Processed velvet has a yield of approximately one third of frozen or fresh velvet, thus the 1983 year's exports were equivalent to around 35 tonnes of fresh velvet.

Statistics on world velvet production are difficult to obtain. China is considered to be both the world's largest producer and consumer of velvet, while Korea is the largest importer. It is possible that current production of high grade velvet is near the maximum volume that can be marketed in an ordinary manner, and it is imperative for producers to obtain information on future trends in the Korean market. Information on the Korean market could help to alleviate potential over-supply problems in the short to medium term.

TABLE 2

Exports of New Zealand Velvet, Totals

Year	FROZEN Volume (kg)	FROZEN Value ($000)	PROCESSED Volume (kg)	PROCESSED Value ($000)	Total Frozen and Processed Value ($000)
1980	2,357	487	2,592	652	1,139
1981	6,033	756	7,541	1,665	2,421
1982	7,229	547	5,874	1,361	1,908
1983	4,899	529	10,207	3,449	3,978

SOURCE: New Zealand Department of Statistics

TABLE 3

Expected Yields and Returns From Velvet At Current Prices (Red Deer)

Age	Weight (kg)[a]	Probable Grade[b]	Return ($/head)
1	-	-	-
2	1.0	D	35
3	1.6	B	112
4	1.9	A	200
5	2.2	Half A, Half Super A	253
6	2.4	Quarter A, Three Quarter Super A	288
6 plus	2.4	" "	288

a. Fennessy and Moore, 1981. Ag. Link, FPP 261
b. Estimated from December 1983 velvet schedule and grades provided by Wrightson NMA Ltd.

Considerable quantities of lower grade velvet from younger animals (B and D grade) may be marketable at lower prices. The likely production strategy for the New Zealand velvet industry is for specialized quality production from selected older animals and a harvest of lower quality velvet as a by-product from younger animals pre-slaughter. This may lead to a marketing strategy based upon two separate products.

Interest is being expressed within the industry in raising wapiti type and wapiti-cross animals for specialist velvet production. Research at Invermay (Moore, 1984) shows wapiti-type rising 2-year-old stags as harvesting a greater weight of velvet than reds. Additionally, velvet from the wapiti type animals was of a better grade than the reds, thus the economic differences between reds and wapiti type is greater than the physical differences.

TABLE 4

Velvet Antler Yields From Rising 2-Year-Old Stags

	BREED		
	Red	Hybrid	Wapiti-Type
Left antler cut at 55 days [a]			
Weight (g)	530	653	800
Value ($/head)	51	82	125
Right antler cut at 65 days			
Weight (g)	690	805	1,005
Value ($/head)	69	126	225

SOURCE: Moore (1984)

a. Days measured as days after casting of old antlers.

These results are based upon the returns from the 1982/83 season. The recommendation for rising 2-year-old stags was to cut red deer antlers at about 60 days, hybrids at 60-65 days, and wapiti at 65-70 days after casting. Changes in either the grading system or grade prices could alter the recommendation.

Further increases in velvet yield may be possible using the Canadian wapiti that have been introduced to New Zealand in the last two to three years. Some doubt exists as to the breeding history of the resident Fiordland wapiti, hence the term wapiti-type, as some crossing with reds may have occurred in the feral state. Early research suggests that the Canadian wapiti may become the most suitable specialist velvet producing animal in the medium term, but this remains an open question at this stage.

Velvet yields shown in Table 3 for each age group are based upon averages, and economic implications of the variability of yields and the predictability of future yields from 2-year-old reds appear to be important avenues of research. Comparisons between superior reds, hybrids, wapiti-type, and Canadian wapiti velvet yields and qualities would enable a clearer perspective to be given to the industry's direction.

2.4 Domestic Herd Size

Information on numbers of deer on New Zealand farms has been published by the Department of Statistics for two years as at June 1981 and June 1982. These figures, shown in Table 5, include all deer, although the red deer predominate (83%). Production data used in the remainder of the paper are for red deer only, thus a bias may be introduced as some fallow, sika, and late wapiti-cross are also farmed.

Over this one year period (1981-82), deer numbers on commercial farms have apparently increased by 38 per cent. An estimated 10,000-12,000 of this increase were captured from feral stock, with the balance being bred on farms. A further increase (10,000-12,000 annually) from captured feral stock, plus two calf drops since June 1982, have increased the population by an amount which is not known at this time.

TABLE 5

Deer On New Zealand Farms

Year	Male	Female	Total
1981	45,000	64,160	109,160
1982	60,670	90,120	150,790
Increase (%)	35	40	38

SOURCE: New Zealand Department of Statistics

The first major survey of the structure and size of the New Zealand deer herd was conducted by M.A.F. during October and November of 1980 (Gladden, 1982). A total of 1,680 farms was surveyed, and details obtained from 1,591 of these. Estimates of total deer on farms were 98,359, comprising 56,560 females and 41,799 males. Comparing this to the Department of Statistics estimates (Table 5) suggests only an 11 per cent rise in total numbers to the 1981 total, with increases of 7.7 and 13.4 per cent in males and females respectively. Intuitively this increase seems too low to be consistent with the Department of Statistics figures - the increase in total females from 1980 to 1981 was 7,603 comparing the two sources, and given a natural increase plus further introduction of feral stock over the time period, a greater percentage increase would be expected. Release of the June 1983 Department of Statistics estimates will provide a further reference point when these become available. Evidence of the rapid increase in numbers of the deer herd is provided by the statement from the M.A.F. survey that 45 per cent of the deer were less than two years of age. A reliable estimate of both numbers and age structure at a base year is important to estimate medium-term growth of the herd, and consequently the Department of Statistics estimates have been used in the paper.

CHAPTER 3

AN ANALYTICAL FRAMEWORK

3.1 Introduction

The background discussion has shown clearly that the supply of velvet and venison is closely linked to both the size and age-structure of the national deer herd. Although changes in the national deer herd can be monitored from an aggregate level, future changes in supply of velvet and venison will depend on individual farmers' decisions about culling in any particular year. In deer production, these decisions are particularly critical because the producer faces a trade-off between killing an animal for venison or retaining that animal either to produce velvet or, in the case of a female, to produce further calves. The problem faced with the slaughter decision for females has been well developed in the cattle industry (Jarvis, 1974) and has been used to explain the seemingly perverse behaviour of a short-term negative supply response. The trade-off which exists for male animals is more unique but has parallels with the models developed by Jarvis (1982), where he discusses the supply of oxen in developing countries.

The nature and complexity of these trade-offs is dependent on the production relationships for velvet and venison as the animal grows. The figures presented in Table 6 outline the key production parameters which have been utilised in this study. The following sections discuss the factors which will influence the producer to slaughter either stags or hinds in any particular year.

3.2 A Theoretical Model of Production Decisions

3.2.1 Stags.

If only venison were produced from a male animal, the value of that animal would be simply the discounted residual value of the animal at slaughter minus the sum of costs involved in keeping the animal through to slaughter age. All costs would be considered, including the opportunity cost of the capital tied up in an animal and the land base and the possibility of an animal dying before slaughter. Appendix A contains a rigorous mathematical derivation of the production decision, and only a simplified version ignoring discounting is presented here as:

$$\pi(\sigma) = p.w - \Sigma ci \qquad (1)$$

where: $\pi(\sigma)$ = value of a male animal at birth if kept till age σ
p = unit price of venison
w = slaughter weight
c = unit costs of inputs over the animal's life
i = amount of inputs
and Σ = summation of the annual costs (c times i), until age σ.

This model is the decision model facing any beef producer with a steer calf, and the producer will maximise returns by feeding an animal the optimal input stream and determining the optimal age of slaughter. The optimal slaughter age is determined mathematically by differentiating (1) with respect to inputs, i, and age, σ. The resultant conditions essentially state that a producer will keep an animal as long as the extra benefits of holding the animal an extra year are greater than the costs involved in keeping the animal for that year.

TABLE 6

Production Characteristics of Red Deer

Age (Years)	Estimated[a] Weight (kg)	Slaughter Value ($)	Probability[b] of Survival to Next Age	VELVET Weight[c] (kg)	VELVET Value[d] ($)	Sheep Equiv-alents
(a) STAGS						
1	42.5	212.5	0.96	-		1.5
2	55	286	0.96	1.0	35	2.0
3	65	345	0.96	1.6	112	2.2
4	70	378	0.96	1.9	200	2.2
5	75	405	0.96	2.2	253	2.2
6	75	405	0.96	2.4	288	2.2
6-12	75	405	0.96	2.4	288	2.2
13	75	405	0.80	2.4	288	2.2
14	75	405	0.50	2.4	288	2.2
(b) HINDS				Weaning %[e]		
2	-	-	-	77		1.5
3-14	55	286	as for stags	86		1.5

a. Estimated from current (December 1983) venison schedule and slaughter weights provided by Canterbury Venison (NZ) Ltd.
b. Estimates only. Figures used at the older age range are artificial, as few animals with a known age at this extreme exist. Probability for hinds is assumed to be the same as for stags.
c. Fennessy and Moore, 1981. Ag. Link FPP 247.
d. Estimated from current (December 1983) velvet schedule and grades provided by Wrightson NMA Ltd.
e. Moore (1983). Ag. Link FPP 247.

Currently most of the benefits from running stags are derived from velvet and not venison, so consequently equation (1) must be modified to incorporate the returns from the annual velvet harvest:

$$\pi(\sigma) = p.w - \Sigma ci + \Sigma p_v w_v \qquad (2)$$

where: p_v = price of velvet
and w_v = weight of velvet produced by an animal, with all other variables as in (1).

As before, the optimal slaughter age, σ, is found by differentiating equation (2). Restructuring the resultant equation (Appendix A) as;

$$p\dot{w} + w\dot{p} + p_v w_v = rpw + ci \qquad (3)$$

where: $\dot{w}$ = the weight gain in the year
and $\dot{p}$ = the change in price,

enables the decision rules for any given year to be seen clearly. The first two terms on the left hand side are the marginal value of venison - the change in weight times the price and the change in price times the weight at slaughter, while the final term refers to the value of velvet produced during the year. The optimal slaughter age is reached when these terms are equated with the interest cost of not slaughtering at the start of the year, and costs (including opportunity cost of sheep farming) incurred during the year. Benefits are assumed to be weighted by the probability of death. Although the animal has a value on the open market, the opportunity cost of capital is considered to be the interest accruing during the year from revenues obtained by slaughtering the animal at the start of the year. Selling the animal on the open market merely transfers the opportunity cost, measured as interest foregone, to another producer. When market values are above slaughter values, this measure of cost will be an underestimation from the farmer perspective, but the true opportunity cost from a national perspective.

Equation (3) provides some insight into why few young stags have been presented for slaughter from domestic stock. Velvet returns have been high enough to dominate equation (3) and ensure that almost all stags were kept for velvet. Only when benefits and cost are equated will a producer offer an animal for slaughter.

3.2.2 Hinds.

The decision model for hinds differs from stags in that velvet is not produced, but there is an income stream generated from the progeny born from the hind. Assuming that each fawn born has an equal chance of being either a male or a female, and ignoring discounting again, then this income stream can be represented as:

$$\frac{1}{2}[\pi_o(\hat{\sigma}) + \rho_o(\hat{\sigma})] F\sigma$$

where: $\pi_o(\hat{\sigma})$ = the value at birth of a male offspring held until the optimal slaughter period;

$\rho_o(\hat{\sigma})$ = the value at birth of a female offspring held until the optimal slaughter period,

and $F\sigma$ = a probability function reflecting the birth rate and mortality of the females at year σ.

Additionally, the hind will have an annual stream of costs associated with farming her (including opportunity costs) and a residual value in slaughter at the end of her economic life. Incorporating these values into an equation with the income stream from the progeny enables a first order condition for profit maximisation to be found similar to equation (3) in the stags. This equation reduces to (Appendix A):

$$\frac{1}{2}[\pi_o(\hat{\sigma}) + \rho_o(\hat{\sigma})]F\sigma + p\dot{w} + w\dot{p} = rpw + ci \qquad (4)$$

with all variables as previously defined, and differs from equation (3) only in that the velvet income from stags is replaced by the income from progeny.

The difficulty in estimating this equation is that the objective is to find the value of a female animal, $p(\hat{\sigma})$, and that same value appears in the equation. Currently with excess demand for capital stock and the deer industry in a development stage, the value of a female calf is greater than would be the case in an equilibrium situation. In an equilibrium situation such as in the cattle or sheep industry, a large proportion of females are in fact slaughtered for meat production at an early age. This in fact usually means that once a decision is made to breed from a female, that female is kept in the herd until the end of her breeding life. Thus the marginal value of a female for breeding must be the slaughter value in an equilibrium situation - if producers consider a female animal is above average she will be kept, otherwise she will be slaughtered for meat. This highlights the observation that the value of a female is ultimately dependent on the value of a male and leads to the simplifying assumption used in this paper, that a female calf has no greater value than a male calf at birth. While the industry is in a state of expansion this will underestimate the value to an unknown degree, thus biasing the calculations of a female's value downwards. Once an equilibrium situation is reached the marginal valuation approach is correct.

The following chapter presents an empirical analysis of the optimal slaughter ages for both stags and hinds.

CHAPTER 4

EMPIRICAL ANALYSIS

4.1 Optimal Slaughter Age of Stags

This chapter utilises the analytical framework to evaluate the age at which a producer should decide to slaughter a stag under different economic conditions. Production data from Table 6 are used for velvet and venison, and are weighted by the probability of survival. Interest costs are assessed at 10 per cent of slaughter value, and reflect the interest which could be earned from the proceeds of the slaughter decision. The gross margin of sheep at $18.37 per stock unit[5] (McGregor, 1983) is used to reflect the opportunity cost of the fixed resources (land, pasture, labour, etc.). Additional annual costs of $15 per stag reflecting special handling costs are also included in subsequent analyses. These data incorporate the information required for equation (3) and can be used to determine the optimal slaughter age of the animal.

Benefits and costs of keeping an animal in each age group for an extra year are shown in Table 7. Column 2 shows the slaughter value at the start of a year while column 3 shows the expected values (adjusted for probability of death) at the end of that year. The difference is shown in column 4, and corresponds to $p\dot{w} + w\dot{p}$ from equation (3). Costs in the form of direct velvet harvesting expenses and the opportunity cost of not raising sheep are shown in column 5, and correspond to the ci component in equation (3). The opportunity cost of interest foregone from not slaughtering at the start of the year (rpw in equation (3)) is shown in column 6, while the final column shows the expected value of velvet (adjusted for probability of death during the year) harvested at the end of the year. This velvet component, $p_v w_v$, completes equation (3).

These benefits and costs are then summed and presented in Table 8, enabling the optimal slaughter age to be determined. Column 2 is a summation of columns 4, 5, 6 and 7 from Table 7, the components of equation (3). If column 2 is a positive value, then the optimal decision is to retain the animal in the herd as the benefits exceed the costs for that year. Under the present venison and velvet pricing structure, it is optimal to keep the animal until the end of year 13 before slaughtering.

---

5. This figure has been adjusted downwards by $2.05 per stock unit to allow for interest charges at 10% on the value of the capital stock required in the sheep production to be consistent with allowing an interest charge on the capital stock used in deer production.

TABLE 7

Calculations for Determining the Optimal Slaughter Age for Stags
(Present Prices for Velvet and Venison)

(1) Age (Start of Year)	(2) Slaughter Value of Animal (Start of Year) ($)	(3) [a] Expected Slaughter Value (End of Year) ($)	(4) Expected Change in Slaughter Value During Year ($)	(5) Opportunity Cost (sheep equivalents) and Direct Velvet Harvesting Costs) ($)	(6) Opportunity Cost of Not Slaughtering at 10% Interest (Col 2) ($)	(7) Expected Value of Velvet at End of Year ($)
0				–27.56		
1	212.5	274.6	+62.1	–42.56	–21.25	33.6
2	286	331.2	+45.2	–51.74	–28.6	107.52
3	345	362.9	+17.9	–55.42	–34.5	192.0
4	378	388.8	+10.8	–55.42	–37.8	242.88
5	405	388.8	–16.2	–55.42	–40.5	276.48
6	405	388.8	–16.2	–55.42	–40.5	276.48
7	405	388.8	–16.2	–55.42	–40.5	276.48
8	405	388.8	–16.2	–55.42	–40.5	276.48
9	405	388.8	–16.2	–55.42	–40.5	276.48
10	405	388.8	–16.2	–55.42	–40.5	276.48
11	405	388.8	–16.2	–55.42	–40.5	276.48
12	405	388.8	–16.2	–55.42	–40.5	276.48
13	405	324.0	–81.0	–55.42	–40.5	230.4
14	405	202.5	–202.5	–55.42	–40.5	144.0

a. From Col. (2), adjusted by probability of death

TABLE 8

Optimal Slaughter Age Decision for Stags

(1) Age (Start of Year)	(2) Summation of Benefits and Costs During Year (Cols 4, 5, 6, and 7) From Table 7 ($)	(3)[a] D.P.V. at 10% ($) (Start of the Year)	(4) D.P.V. at 30% ($)
0		972.94	143.98
1	31.85	1,108.60	233.24
2	72.38	1,240.73	342.16
3	119.96	1,322.81	433.02
4	160.46	1,333.21	482.02
5	164.36	1,293.89	501.14
6	164.36	1,216.59	494.86
7	164.36	1,130.71	485.88
8	164.36	1,035.28	473.06
9	164.36	929.26	454.74
10	164.36	811.45	428.56
11	164.36	680.55	391.17
12	164.36	535.10	337.76
13	53.48	336.15	261.45
14	−154.42		

a. Assumes slaughtering animal at end of year 13, with an expected value (adjusted by probability of death from birth) of $190.57.

Discounted present values (DPV's) of the expected returns from different aged animals are shown in column 3 and 4 for 10 and 30 per cent discount rates respectively. These figures represent the value of the different aged animals in each year under alternative interest rates and assuming slaughtering at the optimal age (13 years). These values are presumed to be indicative of the prices which producers would be prepared to pay for the different aged animals.

Uncertainty about future velvet prices suggests that this exercise should be conducted for a range of expected prices. Exports of velvet were discussed in Section 2.3, but because of carryover effects, and variations in processing methods, caution must be exercised in interpreting the data. Real prices for velvet peaked in 1979 and then dropped dramatically, followed by a slight downward trend since (Figure 2). To test the sensitivity of these results four price scenarios have been developed to reflect more conservative price levels for both velvet and venison. Velvet prices are varied to the greatest extent because they are generally considered to be the most variable, and likely to fall as production increases. The four scenarios are as follows:

A - as used in Table 7, present returns for both venison and velvet;

B - present returns for venison, 0.5 of present returns for velvet;

C - present returns for venison, 0.33 of present returns for velvet; and

D - 0.80 of present returns for venison and velvet returns as in C.

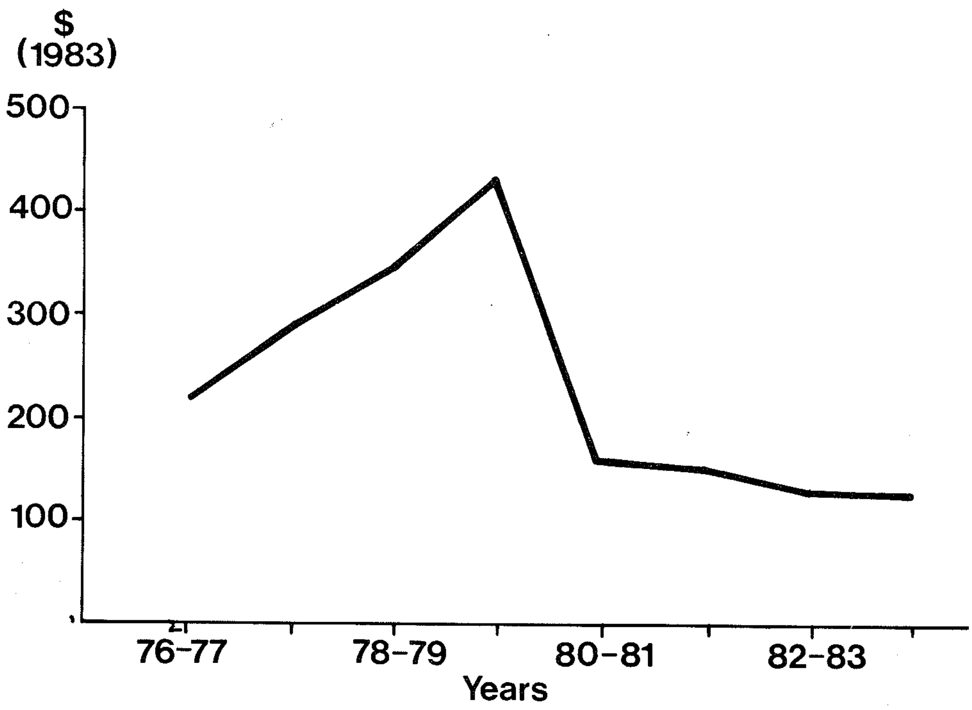
Results of following the decision criteria for scenario B are shown in Table 9, scenario C in Table 10, and scenario D in Table 11. Optimal slaughter age changes from 13 years[6] under scenario A (Table 8) to 12 years under scenario B (Table 9). A more dramatic change occurs under scenario C (Table 10), with velvet returns reduced to one third of present returns. The optimal slaughter age switches from 12 years to 2 years, thus indicating the effect of a drop in returns from velvet production.

These results are indications only as culling a percentage of the stags on velvet production at an early age can be expected to increase mean velvet weights in the remaining animals. Since returns are based on a weight-price relationship, the top producing animals may well be economically viable to continue producing velvet. This analysis is outside the scope of the present study, but suggests a fruitful avenue for future research.

----

6. A 13 year old in this analysis is effectively a 14 year old animal. Calves are born in December, and velvet harvested in November. Thus a decision to keep an animal from 13 to 14 years would mean the animal is 14 years old at the end of the time period, but is referred to as a 13 year old. A similar interpretation applies for all ages.

Figure 2. Velvet Prices, Super A Grade 1983 Dollars



Source: (a) Ritchie and Giles, up to 1980
(b) Wrightson N.M.A. pers com; after 1980

TABLE 9

Optimal Slaughter Age For Stags, Scenario B
(Velvet 0.5 of Present Returns, Venison Present)

(1) Age (Start of Year)	(2) Expected Change in Slaughter Value During Year ($)	(3) Opportunity and Direct Costs (Cols 5 and 6, Table 7) ($)	(4) Expected Velvet Return ($)	(5) Summation of Cols 2, 3 and 4) ($)	(6)[a] D.P.V. at 10% (Start of Year) ($)
0		-27.56	—	-27.56	336.78
1	+62.1	-63.81	16.80	+15.05	399.96
2	+45.2	-80.34	53.76	+18.62	470.16
3	+17.9	-89.92	96.0	+23.96	520.38
4	+10.8	-93.22	121.44	+39.02	537.62
5	-16.2	-95.92	138.24	+26.12	531.33
6	-16.2	-95.92	138.24	+26.12	507.55
7	-16.2	-95.92	138.24	+26.12	481.12
8	-16.2	-95.92	138.24	+26.12	451.76
9	-16.2	-95.92	138.24	+26.12	419.14
10	-16.2	-95.92	138.24	+26.12	382.89
11	-16.2	-95.92	138.24	+26.12	342.61
12	-16.2	-95.92	138.24	+26.12	297.86
13	-81.0	-95.92	115.2	-61.72	
14	-202.5	-95.92	72.0	-226.42	

a. Slaughter value at end of the year = $284.15 in expected value.

TABLE 10

Optimal Slaughter Age for Stags, Scenario C
(Venison present return, Velvet 0.33 present returns)

(1)	(2)	(3)	(4)[a]
Age (Start of year)	Expected Returns Velvet ($)	Decision — Col 2, plus Cols 2 and 3 from Table 9 ($)	D.P.V. at 10% ($)
0			117.51
1	11.20	9.45	156.33
2	35.84	0.70	205.06
3	64.00	−8.05	
4	80.45	−1.47	
5	92.15	−19.97	

a. Slaughtering end of year 2, with an expected value at birth of $263.58

TABLE 11

Optimal Slaughter Age for Stags, Scenario D
(Venison 0.80 present return, Velvet 0.33 present returns)

(1) Age (Start of year)	(2) Expected change in Slaughter Value During Year ($)	(3) Opportunity and Direct Costs ($)	(4) Expected Velvet Returns ($)	(5) Criteria — Cols 2, 3, and 4 ($)	(6)[a] D.P.V. at 10% ($)
0		−27.56		−27.56	110.56
1	+49.68	−59.56	11.20	+1.29	150.41
2	+36.16	−74.62	35.84	−2.62	198.48
3	+14.32	−83.02	64.00	−4.73	236.43
4	+8.64	−85.46	80.95	+3.93	254.13
5	−12.96	−87.82	92.15	−8.63	

a. Slaughtering at end of year 4, with expected value of $256.84 at birth.

Decreasing venison returns by 20 per cent (scenario D) alters the optimal slaughter age once again - from 2 to 4 years.[7] This is a result of a lower opportunity cost in keeping the animal a further year (interest foregone). However, implications of a change in velvet returns of this magnitude are clear, in that keeping the average velvet producing animal in the herd past the optimal slaughter age incurs an opportunity cost to the producer. One avenue of research not pursued is whether this would incur an opportunity cost to the nation. Information on elasticities for velvet and the exclusion of S.M.P.s (Supplementary Minimum Prices) from the sheep gross margins to establish true opportunity costs to the nation would be needed to complete this analysis.

Results from the four scenarios are summarised in Table 12.

TABLE 12

Summary Of Slaughter Decisions

	SCENARIO A	B	C	D
Velvet Returns	Present	0.5x Present	0.33x Present	0.33x Present
Venison	Present	Present	Present	0.8x Present
Optimal Age (End of Year)	13	12	2	4
D.P.V. 10% Birth ($)	972.94	336.78	117.51	110.56
D.P.V. 10% 1 Year ($)	1108.60	394.96	156.33	150.41
Residual Slaughter Value ($)	190.57	248.15	263.58	256.84

7. The decision criterion is actually negative in two time periods, but becomes positive in year 4. Although it is strictly speaking sub-optimal to continue until year 4, the analysis has been conducted in this way to demonstrate the effect of venison price changes. Actual differences are $3.02 from an optimal kill at end of Year 2.

4.2 Optimal Slaughter Age of Hinds

The value of female calves are ultimately determined by the male calves they produce and a residual slaughter value. Once herd sizes stabilise and the number of females born exceeds that required for breeding, producers will be indifferent between slaughtering surplus stock or keeping that same stock in the herd for breeding progeny.[8] Thus the marginal value of a female will be the discounted net slaughter value, and the value of an animal retained for breeding will be the net discounted stream of future returns generated by that animal. Table 13 presents the results of calculations for a female calf based upon the assumption that all calves born have the same valuation as male calves at weaning (Table 12). Such a valuation will, of course, understate the future income stream as long as herd numbers are increasing and future female calves have a higher marginal value in breeding than in slaughtering.

Opportunity costs of maintaining a hind are estimated to be $18.37 until one year of age and $27.56 thereafter (1.0 and 1.5 stock units respectively). The undiscounted value of the progeny at birth is considered to be the D.P.V. at weaning of a male calf from Table 12, weighted by the probability of a calf being born. Exactly the same decision criterion applies to the hind slaughter as does to the stag slaughter decision, and this is shown in Table 13 (summarised in Table 14). Marginal benefits are the value of progeny, and the expected change in venison value, while the costs include interest foregone on venison value, and opportunity costs of running sheep. Moving from scenario A to D changes the optimal slaughter age as shown in Table 13. The marginal opportunity costs of capital are decreased from scenario C to scenario D, resulting in an increase in slaughter age.

---

8. These conditions are discussed in Jarvis (1984), and are derived mathematically in Sandrey (1982) with reference to a North American elk (wapiti) herd.

TABLE 13

Decision Criteria For Hinds Under Alternative Scenarios ($)

Year	Probability of Calving Start Yr	Opportunity Cost ($)	A: Expected Value of Offspring in Each Year ($)	A: Discounted Future Returns at Each Year ($)	B: Expected Value of Offspring in Each Year ($)[a]	B: Discounted Future Returns at Each Year ($)	C: Expected Value of Offspring in Each Year ($)[a]	C: Discounted Future Returns at Each Year ($)	D: Expected Value of Offspring at Each Year ($)[a]	D: Discounted Future Returns at Each Year ($)
			(972.94)[a]		(336.78)[a]		(117.51)[a]		(110.56)[a]	
0	—	-18.37		3168.71		998.12		250.15		229.19
1	—	-27.56		3539.16		1127.40		296.31		273.02
2	.71	-27.56	690.79	3969.96	239.12	1280.22	83.43	356.80	78.50	330.92
3	.76	-27.56	739.43	3736.73	255.95	1210.91	89.31	340.57	84.03	316.75
4	.73	-27.56	710.25	3440.05	245.85	1117.07	85.78	316.66	80.71	295.47
5	.70	-27.56	681.06	3139.59	235.75	1022.89	82.26	293.63	77.39	275.15
6	.67	-27.56	652.81	2834.93	225.64	928.36	78.73	271.55	74.08	255.89
7	.65	-27.56	632.41	2524.61	218.91	833.43	76.38	250.55	71.86	237.80
8	.62	-27.56	603.22	2200.28	208.80	734.68	72.86	229.57	68.55	219.93
9	.60	-27.56	583.76	1869.09	202.07	635.07	70.51[b]	209.78	66.34	203.37
10	.57	-27.56	554.58	1520.57	191.96	531.13	66.98		63.02	187.19
11	.55	-27.56	535.12	1162.50	185.23	425.74	64.63		60.81[b]	172.53
12	.49	-27.56	476.74	783.11	165.02	315.38	57.58		54.17	
13	.37	-27.56	359.99[b]	422.05	124.61[b]	212.96	43.48		40.90	

a. From Table 12, D.P.V. of male at birth.
b. Optimal age to retain hind.

TABLE 14

Summary of Hind Decision Criteria

	SCENARIO A	B	C	D
Optimal Slaughter Age (End of Year)	13	12	9	11
D.P.V. at Birth (Weaning) at 10% ($)	3168.71	998.12	250.15	229.19
Residual Value Adjusted by Prob. ($)	139.57	168.23	190.14	158.45
Value of Calf at Birth ($)	972.94	336.78	117.51	110.56
Value of Calf at 1 Year Old ($)	1108.60	394.96	156.33	150.41
Marginal Cost at Age 10 Years ($)	67.60	67.60	67.60	59.59

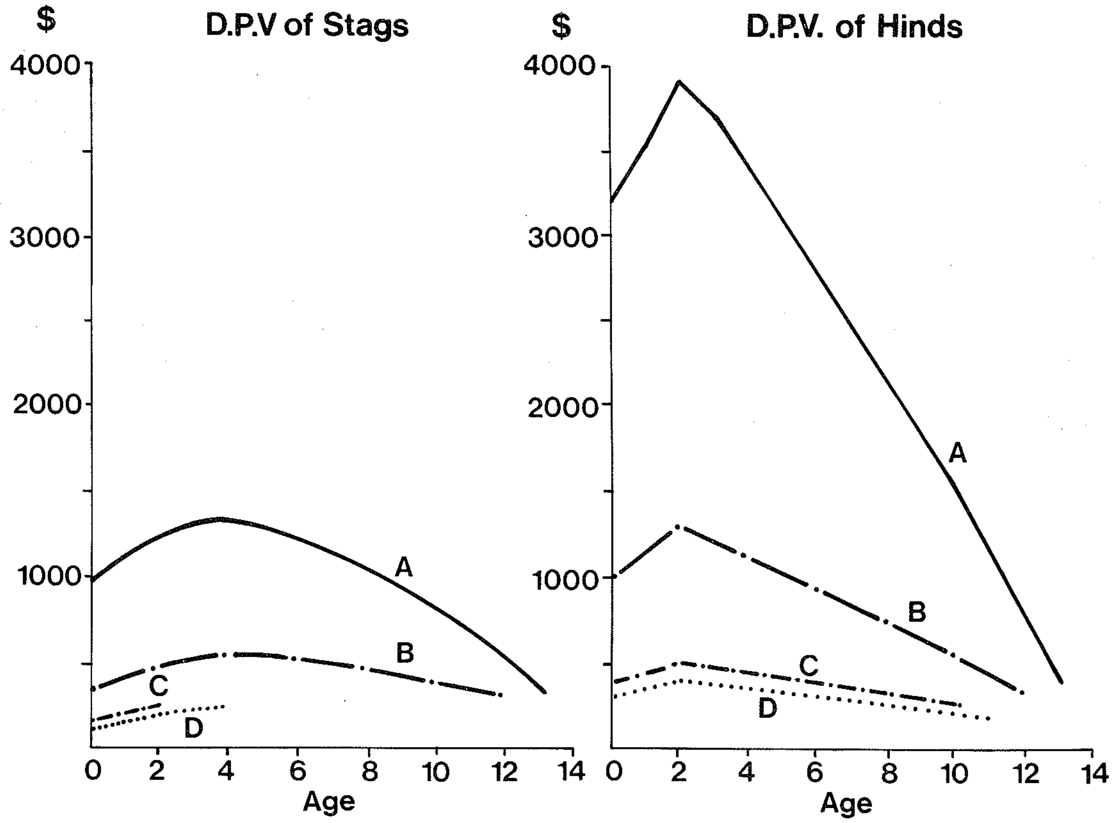
Discounted present values for 10 per cent are graphed in Figure 3 for males (I) and females (II) under the alternative scenarios used in the paper.

4.3 Capital Value of An Animal

The maximisation of the net returns to producers over time is equivalent to the maximisation of the net D.P.V. of each animal. Assuming that the animal is fed the optimal input stream, $\hat{i}$, determining the optimal slaughter age maximises this net present value, and this is equivalent to the capital value of the animal at any particular age, σ. Thus, the D.P.V.s reported in Tables 12 and 14 and graphed in Figure 3 represent the amount a rational producer would pay for different aged animals under the alternative price scenarios. Recall that these D.P.V.s have opportunity cost (sheep production) incorporated, and are discounted by 10 per cent unless otherwise stated.

Optimal slaughter age can be affected by a change in either venison or velvet prices, and in fact, this has been demonstrated using a scenario approach. Effects of these and other exogenous changes can be studied using equation (3). A change in the price of venison will affect both sides via the direct price effect on the left hand side and

Figure 3. Discounted Present Values of Deer



indirectly via the opportunity cost of capital on the right hand side. One may not be able to make unequivocal statements regarding the magnitude of such a change, but the sign would be positive. In the cattle industry, the effects of long-run price changes may be constrained by fixed availability of resources (mainly grazing land), but this constraint probably does not restrict the domestic deer industry in the short-term future. Changes in velvet values will be positive, and changes in both interest rates and costs (including the opportunity cost of producing sheep) will be negative.

These same changes will of course alter the D.P.V. of an animal, and this will alter the value of a female. Following an increase in either venison or velvet prices, the capital price of a young female would rise relative to a young male. This would be expected because the female value is directly a function of the stream of benefits from male progeny. Also, a rise in female values relative to males would accentuate the understatements of female values caused by assuming a male progeny value for the income stream.

The optimal slaughter ages and values do not provide a direct measure of the supply response elasticities for venison or velvet but these can be approximated by utilising the decision rules in a simulation model of the commercial deer population.

CHAPTER 5

FUTURE PROJECTIONS

Using the slaughter age decision criteria formulated in Chapter 4, a computer simulation model was developed to estimate herd build up and projected production in the medium term. This model is based upon estimates of the current age structure of the commercial herd. Because of the new nature of the industry, this herd is biased towards younger animals. Population and production parameters are as previously used, with an additional 2 per cent and 3 per cent annual slaughter of hinds and stags respectively for all age groups up to the optimal age. This culling is presumed to account for obvious defects in individual animals. A live capture of a constant 11,500 animals per annum is assumed (Wallis, 1983).

Projections under present conditions (scenario A) until 1991 are shown in Table 15. This table clearly demonstrates the potential build up of deer over the time period, and the resultant projected farmed venison production if velvet returns remain at present levels. The actual herd increase from 1981 to 1982 was 38 per cent (Table 5), the same as estimated. Increases in herd numbers decline through time, as the impact of live capture animals is reduced with increasing domestic herd build-up. Total farm venison slaughtered rises only slowly as animals move through the herd, and reaches a peak at 2,915 tonnes by 1991.

Estimates of velvet production differ dramatically from the actual as reported by the Department of Statistics (Table 2). Using the herd size and structure discussed in Section 2.1, and making the assumptions of velvet yield from Section 2.2, potential yield appears to be about double the actual. Bias introduced by assuming an all red deer herd may account for some of this difference, as may the assumption that Invermay velvet yields (Section 2.1) represent a New Zealand wide situation. Additionally, sub-optimal harvest decisions may mean that an average yield comparable to the Invermay herd is not reached by many producers. Difficulties in obtaining accurate information highlight the need for accurate forecasts to be available to producers.

TABLE 15

Projections of Deer Numbers and Production

Year Ending June	Hinds ('000) (as at June)	Total Deer ('000)	% Increase Total Deer	Venison (Tonnes)	Velvet
		SCENARIO A			
1981	64	109	-	241	50
1982	90	151	38	327	67
1983	120	203	35	403	90
1984	158	270	33	533	122
1985	205	356	32	696	165
1986	264	467	31	906	244
1987	337	605	30	1,150	302
1988	426	776	28	1,448	401
1989	536	990	27	1,816	529
1990	671	1,254	27	2,297	691
1991	839	1,584	26	2,915	894
		SCENARIO C			
1983	120	203	33	403	90
1984	158	270	32	6,090 [a]	122
1985	205	357	3	2,466	96
1986	236	367	22	3,175	121
1987	286	449	21	3,798	146
1988	348	545	21	4,671	180
1989	422	662	21	5,707	218
1990	513	805	21	6,976	265
1991	622	976	21	8,450	321

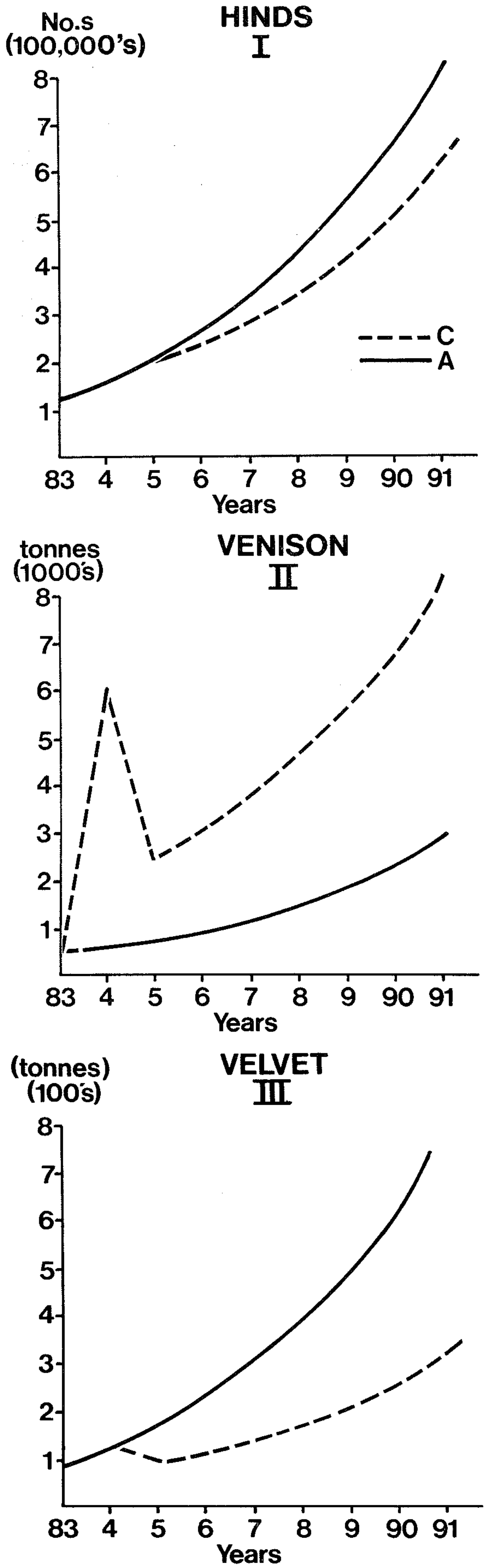
a. This figure represents a 40 per cent increase on venison exports for the peak feral year, 1972.

The estimate from scenario A represents the most optimistic velvet return scenario, and can be regarded as the lowest potential venison production in the medium term. Scenario C, velvet returns one-third of present and venison the same as present represents the highest venison production over the same period. Recall slaughter age is reduced to two years for stags and 9 years for hinds. No live capture of hinds is assumed post-1984, as live capture probably would not be viable under a lower hind value. It is unlikely, of course, that producers would react in this manner to a sudden fall in velvet prices; an adjustment period whereby expectations changed over a period of greater than one season would be more realistic.

Differences between the two scenarios are apparent, and these are reproduced in Figure 4. Altering the optimal slaughter age of hinds has little impact upon numbers of hinds; most of the reduction shown in (I)is probably due to cessation of live capture. Dramatic differences are apparent in venison production (II), highlighting uncertainty in the venison processing industry as to future supplies.

Changes in potential velvet production under the two alternative scenarios are also shown in Figure 4. Estimated velvet production for the years ending June 1982 and 1983 was lower than the simulated figures shown. Differences in processing yields and holding over of supplies makes estimation of actual production difficult as discussed, while uncertainty as to the current age distribution of stags already in the herd makes forecasting tenuous. There is little doubt, however, that velvet production can, and would, increase rapidly if present returns hold.

Figure 4. Potential Deer Numbers, Venison and Velvet Production



CHAPTER 6

CONCLUSIONS AND IMPLICATIONS

The models developed in this study are useful in providing some insight into the individual's decision making process on the optimal slaughter age of animals, and how factors influencing this decision are likely to effect the medium term growth in the New Zealand commercial deer industry. The lack of historical data precludes the development of a formal econometric model, but the use of price scenarios does allow some important implications to be drawn for the medium term.

The analysis of optimal slaughter ages is important in understanding the current lack of venison supply. The analysis showed that under current prices it is profitable for producers to retain both stags and hinds until fourteen years, which is close to their life expectancy. This situation would lead to the maximum possible build-up in both hind and stag herds and the minimum supply of venison from cull stock. The optimal slaughter age was seen to be most sensitive for stags, and a drop in velvet returns to 33% of their current levels would lead to a major emphasis on venison production and increased production in the short and medium term. Even at these price levels it appears that slaughter ages for hinds would be maintained and the herd size would increase.

The derived values of livestock also contribute to exploring the current situation. The results suggest that weaner hinds and stags at current prices, and a 10 per cent discount rate would have current values of approximately $3,200 and $1,000 respectively. These values can be contrasted with those suggested in a recent industry statement:

> "... the payment of unrealistically high prices in excess of $2,500 for mixed age hinds and $2,000 for 18 month hinds should be viewed as exceptional and applicable to a very small proportion of hinds traded from March to October this year. It is also interesting to note that relatively few deer farmers or investors have been persuaded by talk of such prices to take their profit by offering large numbers of hinds for sale ... the rationale for high prices for weaner stags and spikers (young stags) is more difficult to assess. It is commonly held by experienced members of the industry that a weaner stag is not a viable proposition for venison production if purchased for more than approximately $140. In this context prices in excess of $200 at auction make little sense."[9]

---

9. An Assessment of Current Trends by Michael Pattison, Executive Director, New Zealand Deer Farmers Association (NZDFA), Stagline, November 1983.

The values presented in the above statement suggest that market values understate the current values of these animals, and provide an explanation of why producers are currently retaining both hinds and stags. The values derived in this study also suggest that stags are relatively more under-valued than hinds, but this may be a reflection of the manner in which female offspring were valued in the analysis.

It is possible that the difference between the actual and estimated values are caused by producers' attitudes to risk. It is interesting to note that for stags, a discount rate of approximately 35 per cent or a drop in velvet prices to below 50 per cent of their current level would produce valuations similar to the current market. These figures suggest relatively high margins for risk.

The results from the population simulation model show two extremes of time-paths for the industry development. In both cases the profitability of deer in comparison to sheep farming suggest that the female herd will continue to grow, although at a lesser rate as velvet prices fall.

The major impact of lower velvet prices would be in a rapid change in venison output. Multipliers which measure the impact of a fall in velvet prices on both venison and velvet production were computed from Table 15 and are presented in Table 16. Although the changes are accentuated by the nature of the simulation model, a change from retaining stags to 13 years, to only several years, could produce a dramatic surge in venison production as numbers are decreased. These effects would certainly be moderated by falling market prices, but it is the type of reaction which a co-ordinated marketing plan would wish to avoid. It is important to note that the multipliers are not symmetric for a rise in velvet price. Because the herd is currently growing, at its maximum rate there would be minimal increases in production from such a price rise. The changes in velvet production are smaller, but reflect the fall in stag numbers. These falls are not as dramatic as might be expected, but this is a reflection of the age structure of the herd and the low base level of venison production at the present time.

TABLE 16

Percentage Change in Output From A Sustained One Per Cent Decrease in Velvet Prices

Year	Velvet Production	Venison Production
0	0	16
1	-0.63	4
2	-0.76	4
3	-0.78	3.5
4	-0.83	3.5

The greatest danger for the industry at present is that a substantial drop in velvet returns could set off a large reaction such that hind growth rate is reduced, venison production increases, and market prices fall in a relatively short period.

Although these models provide only crude projections, they are a necessary first step for producers and policymakers to understand the dynamics involved in a new and rapidly growing industry.

REFERENCES

Bank of New Zealand (1983), "The New Zealand Deer Farming Industry". Economics Department Industry Report No. 16.

Fennessy, P.F. and Moore, S.H. (1981), "Deer : Red Deer Velvet Antler Growth and Harvesting". Ag. Link FPP261, M.A.F. Media Services, Wellington.

Gladden, N. (1982), "Deer Population and Health Survey 1980". AgLink No. FPP259, M.A.F. Media Services, Wellington.

Jarvis, Lovell S. (1974), "Cattle As Capital Goods and Ranchers As Portfolio Managers : An Application to the Argentine Cattle Sector". Journal of Political Economics, 82(1974), pp.489-520.

Jarvis, Lovell S. (1982), "To Beef Or Not To Beef? Portfolio Choices of Asian Smallholder Cattle Producers". In Livestock in Asia : Issues and Policy, J.C. Fine and R.G. Lattimore, Eds, International Development Research Centre, Ottawa, Canada.

Moore, G.H. (1984), "Evaluation of Wapiti in Deer Farming". Agricultural Research in the New Zealand M.A.F., Annual Report of the Research Division, 1982-83.

Moore, G.H. (1983), "Deer : Red Deer Calving and Weaning". Ag. Link FPP247, M.A.F. Media Services, Wellington.

McGregor, M.J. (1983), "Sheep Gross Margins". In 1983 Farm Budget Manual, M.B. Clark and G.P. Rennie, Eds, Department of Farm Management and Rural Valuation, Lincoln College.

New Zealand Deer Farmers Association (1983), "An Open Letter from New Zealand Game Industry Association". Stagline, No. 68, NZDFA, Wellington.

New Zealand Deer Farmers Association (1983), "An Assessment of Current Trends". Michael Pattison, Executive Director, NZDFA, Stagline, No. 71, NZDFA, Wellington.

Ritchie, J.M.W. and Giles, K.H. (1982), "Deer Economics : Red Deer Farming". Ag. Link FPP250, M.A.F. Media Services, Wellington.

Sandrey, R.A. (1982), "Economic Considerations in Managing Oregon Rocky Mountain Elk". Unpublished Ph.D. Dissertation, Department Resource Economics, Oregon State University, Corvallis, Oregon.

Sandrey, R.A. and Zwart, A.C. (1983), "Dynamic Considerations in Managing New Zealand's Feral Deer Herd". Contributed paper to 8th Annual Conference of N.Z. Branch of Australian Agricultural Economics Society, Wellington, August 1983.

Wallis, T.W. (1983), "Is it Too Late to Start Deer Farming". Paper presented at Hill and High Country Seminar, Lincoln College, May 1983.

APPENDIX A

A THEORETICAL MODEL OF PRODUCTION DECISIONS - MATHEMATICAL DERIVATION

Starting from a simple model where only venison is produced from the male animal, the value of a stag at birth (weaning) can be represented as follows (Jarvis, 1974):

$$\pi(\sigma) = p(i,\sigma)w(i,\sigma)e^{-r\sigma} - ci\int_o^{\sigma} e^{-rt}dt \qquad (5)$$

where: $\pi(\sigma)$ = value of male animal at birth,
p = unit price of venison,
w = slaughter weight,
c = unit cost of inputs over life,
i = amount of inputs per unit time,
r = interest rate,
and σ = age of animal.

The producer can maximise the value $\pi(\sigma)$ by choosing the optimal input stream $(\hat{i})$ and age of slaughter $(\hat{\sigma})$. This is accomplished by differentiating (5) with respect to inputs, i, and age, σ. The resultant first order condition is essentially the familiar equating of marginal benefits and marginal costs.

Currently most of the benefit is derived from velvet production and not venison, so consequently equation (5) must be modified to incorporate the returns from the annual velvet harvest:

$$\pi(\sigma) = p(i,\sigma)w(i,\sigma)e^{-r\sigma} + \int_o^{\sigma} p_v(i,\sigma)w_v(i,\sigma)e^{-rt}dt - ci\int_o^{\sigma} e^{-rt}dt \qquad (6)$$

where: p_v price of velvet,
and w_v weight of velvet produced by an animal at age having been fed input stream i, with all other variables as in (5).

As before, and assuming that animals are fed optimally, the optimal slaughter age, T, is found by differentiating (6).

$$\frac{\partial\pi}{\partial\sigma} = e^{-r\sigma}\left[P\frac{\partial w}{\partial\sigma} + w\frac{\partial p}{\partial\sigma}\right] - rpwe^{-r\sigma} + p_v(i,\sigma)w_v(i,\sigma)e^{-r\sigma}$$

$$- cie^{-r\sigma} \qquad (7)$$

Dividing (7) through by e^{-rt}, setting equal to zero, and restructuring as

$$p\dot{w} + w\dot{p} + p_v w_v = rpw + ci \qquad (8)$$

enables the first order conditions discussed in Chapter 4 to be shown more clearly.

The first two terms on the left hand side are the marginal value of venison (the change in weight times the price and the change in price times the weight at slaughter), while the final term refers to the value of velvet produced during the year. Optimality is reached when these terms are equated to interest from venison slaughter at the start of the year and costs (including opportunity cost of sheep) incurred during the year. Benefits are assumed weighted by the probability of death.

The theoretical decision model for hinds differs from stags in that velvet is not produced, but there is an income stream generated from the progeny produced.

This income can be represented as follows:

$$\tfrac{1}{2}[\pi_o(\hat{\sigma}) + p_o(\hat{\sigma}) {}_o\!\int^{\sigma} F(i,\sigma) d^{-rt} dt$$

where: $\pi_o(\hat{\sigma})$ = the value at birth of a male offspring held until the optimal slaughter period,
$p_o(\hat{\sigma})$ = the value at birth of a female offspring held until the optimal slaughter age,
$F(i,\sigma)$ = a probability function reflecting the birth rate and mortality of the female.

Incorporating this relationship into the venison only equation (5) enables the profit function for young females to be specified:

$$p_o(\sigma) = \tfrac{1}{2}\pi(\sigma) + p_o(\hat{\sigma})] {}_o\!\int^{\sigma} F(i,\sigma) e^{-rt} dt + p(i,\sigma) w(i,\sigma) e^{-r\sigma}$$

$$- ci {}_o\!\int^{\sigma} e^{-rt} dt \qquad (9)$$

By differentiating the equation with respect to and simplifying it is possible to derive the first order condition which can be used to determine the optimal slaughter age for females:

----

10. To ensure a global optima, second order conditions must of course be satisfied. Given the nature of the production function, this may be important, as a local optima may occur at an early age.

$$\tfrac{1}{2}[\pi_o(\hat{\sigma}) + p_o(\hat{\sigma})]F(i,\sigma) + p\dot{w} + w\dot{p} = rpw + ci \qquad (10)$$

This relationship is similar to that derived for stags except that the income from velvet is replaced by the first term in equation (10), which measures the income associated with the offspring produced.

The difficulty associated with measuring this income stream is that the value of female offspring is endogenous to equation (9). This highlights the observation that the value of the female animal is ultimately dependent on the value of the male and leads to the simplifying assumption used in the paper.

RECENT PUBLICATIONS

RESEARCH REPORTS

115. *A Socio-Economic Study of Farm Workers and Farm Managers,* G.T. Harris, 1980.
116. *An Economic Survey of New Zealand Wheatgrowers: Financial Analysis, 1978-79,* R.D. Lough, R.M. MacLean, P.J. McCartin, M.M. Rich, 1980.
117. *Multipliers from Regional Non-Survey Input-Output Tables for New Zealand,* L.J. Hubbard, W.A.N. Brown, 1981.
118. *Survey of the Health of New Zealand Farmers: October-November 1980,* J.G. Pryde, 1981.
119. *Horticulture in Akaroa County,* R.L. Sheppard, 1981.
120. *An Economic Survey of New Zealand Town Milk Producers, 1979-80,* R.G. Moffitt, 1981.
121. *An Economic Survey of New Zealand Wheatgrowers: Enterprise Analysis, Survey No. 5 1980-81,* R. D. Lough, P. J. McCartin, M.M. Rich, 1981.
122. *An Economic Survey of New Zealand Wheatgrowers: Financial Analysis 1979-80,* R.D. Lough, P.J. McCartin, M.M. Rich, 1981.
123. *Seasonality in the New Zealand Meat Processing Industry,* R.L. Sheppard, 1982.
124. *The New Zealand Wheat and Flour Industry: Market Structure and Policy Implications,* B.W. Borrell, A.C. Zwart, 1982.
125. *The Ecomomics of Soil Conservation and Water Management Policies in the Otago High Country,* G.T. Harris, 1982.
126. *Survey of New Zealand Farmer Intentions and Opinions, September-November, 1981,* J.G. Pryde, 1982.
127. *The New Zealand Pastoral Livestock Sector: An Econometric Model (Version Two),* M.T. Laing, 1982.
128. *A Farm-level Model to Evaluate the Impacts of Current Energy Policy Options,* A.M.M. Thompson, 1982.
129. *An Economic Survey of New Zealand Town Milk Producers 1980-81,* R.G. Moffitt, 1982
130. *The New Zealand Potato Marketing System,* R.L. Sheppard, 1982.
131. *An Economic Survey of New Zealand Wheatgrowers: Enterprise Analysis, Survey No. 6, 1981-82,* R.D. Lough, P.J. McCartin, M.M. Rich, 1982.
132. *An Economic Survey of New Zealand Wheatgrowers: Financial Analysis, 1980-81,* R.D. Lough, P.J. McCartin, 1982.
133. *Alternative Management Strategies and Drafting Policies for Irrigated Canterbury Sheep Farms,* N.M. Shadbolt, 1982.
134. *Economics of the Sheep Breeding Operations of the Department of Lands and Survey,* A.T.G. McArthur, 1983.
135. *Water and Choice in Canterbury,* K.L. Leathers, B.M.H. Sharp, W.A.N. Brown, 1983
136. *Survey of New Zealand Farmer Intentions and Opinions, October-December, 1982,* J.G. Pryde, P.J. McCartin, 1983.
137. *Investment and Supply Response in the New Zealand Pastoral Sector: An Econometric Model,* M.T. Laing, A.C. Zwart, 1983
138. *The World Sheepmeat Market: an econometric model,* N. Blyth, 1983.
139. *An Economic Survey of New Zealand Town Milk Producers, 1981-82,* R.G. Moffitt, 1983.
140. *Economic Relationships within the Japanese Feed and Livestock Sector,* M. Kagatsume, A.C. Zwart, 1983.
141. *The New Zealand Arable Sector: Foreign Exchange Implications,* R.D. Lough, W.A.N. Brown, 1983.
142. *An Economic Survey of New Zealand Wheatgrowers: Enterprise Analysis, Survey No. 7, 1982-83,* R.D.Lough, P.J. McCartin, 1983.
143. *An Economic Survey of New Zealand Wheatgrowers: Financial Analysis, 1981-82,* R.D. Lough, P.J. McCartin, 1983.
144. *Development of the South Canterbury-Otago Southern Bluefin Tuna Fishery,* D.K. O'Donnell, R.A. Sandrey, 1983.
145. *Potatoes: A Consumer Survey of Auckland, Wellington and Christchurch Households,* R.L. Sheppard, S.A. Hughes, 1983.
146. *Potatoes: Distribution and Processing,* S.A. Hughes, R.L. Sheppard, 1983.
147. *The Demand for Milk: An Econometric Analysis of the New Zealand Market,* R.J. Brodie, R.G. Moffitt, J.D. Gough, 1984.
148. *The Christchurch and New Zealand Eating Out Markets,* A. van Ameyde, R.J. Brodie, 1984.
149. *The Economics of Controlling Gorse in Hill Country: Goats versus Chemicals,* M.A. Krause, A.C. Beck, J.B. Dent, 1984.
150. *The World Market for Fruit Juice Products: Current Situation and Prospects,* M.T. Laing, R.L. Sheppard, 1984.
151. *The Economics of Controlled Atmosphere Storage and Transport for Nectarines, Apples and Kiwifruit,* M.T. Laing, R.L. Sheppard, 1984.
152. *Survey of New Zealand Farmer Intentions and Opinions. October-December, 1983,* J. G. Pryde, P. J. McCartin, 1984.
153. *Dynamics of Herd Buildup in Commercial Deer Production,* R. A. Sandrey, A. C. Zwart, 1984.

DISCUSSION PAPERS

61. *An Evaluation of Farm Ownership Savings Accounts,* K.B. Woodford, 1981.
62. *The New Zealand Meat Trade in the 1980's: a proposal for change,* B.J. Ross, R.L. Sheppard, A.C. Zwart, 1982.
63. *Supplementary Minimum Prices: a production incentive?* R.L. Sheppard, J.M. Biggs, 1982.
64. *Proceedings of a Seminar on Road Transport in Rural Areas,* edited by P.D. Chudleigh, A.J. Nicholson, 1982.
65. *Quality in the New Zealand Wheat and Flour Markets,* M.M. Rich, 1982.
66. *Design Considerations for Computer Based Marketing and Information Systems,* P.L. Nuthall, 1982.
67. *Reaganomics and the New Zealand Agricultural Sector,* R.W. Bohall, 1983.
68. *Energy Use in New Zealand Agricultural Production,* P.D. Chudleigh, Glen Greer, 1983.
69. *Farm Finance Data: Availability and Requirements,* Glen Greer, 1983
70. *The Pastoral Livestock Sector and the Supplementary Minimum Price Policy,* M.T. Laing, A.C. Zwart, 1983.
71. *Marketing Institutions for New Zealand Sheepmeats,* A.C. Zwart, 1983.
72. *Supporting the Agricultural Sector: Rationale and Policy,* P.D. Chudleigh, Glen Greer, R.L. Sheppard, 1983.
73. *Issues Related to the Funding of Primary Processing Research Through Research Associations,* N. Blyth, A.C. Beck, 1983.
74. *Tractor Replacement Policies and Cost Minimisation,* P.L. Nuthall, K.B. Woodford, A.C. Beck, 1983.
75. *Tomatoes and the Closer Economic Relationship with Australia,* R.L. Sheppard, 1983.
76. *A Survey of Farmers' Attitudes to Information,* R.T. Lively, P.L. Nuthall, 1983.
77. *Monetary Policy and Agricultural Lending by Private Sector Financial Institutions,* R.L. St. Hill, 1983.
78. *Recreational Substitutability and Carrying Capacity for the Rakaia and Waimakariri Rivers,* B. Shelby, 1983.
79. *"Consider Japan": Papers from a Seminar Conducted by the Japan Centre of Christchurch,* Edited by R.G. Moffitt, 1984.
80. *Deregulation: Impact on the Christchurch Meat Industry,* R.L. Sheppard, D.E. Fowler, 1984.
81. *Farmers Record Keeping and Planning Practices: a postal survey,* J. Ryde, P.L. Nuthall, 1984.
82. *The State of Agricultural Credit in New Zealand,* J. G. Pryde, L. B. Bain, 1984.
83. *The Future of the Common Agricultural Policy and its Implications for New Zealand,* E. A. Attwood, 1984.

Additional copies of Research Reports, apart from complimentary copies, are available at $6.00 each. Discussion Papers are usually $4.00 but copies of Conference Proceedings (which are usually published as Discussion Papers) are $6.00. Discussion Paper No. 60 is available at $4.00 per volume ($20 for the set). Remittance should accompany orders addressed to: Bookshop, Lincoln College, Canterbury, New Zealand. Please add $0.90 per copy to cover postage.