AGRICULTURAL
ECONOMICS
RESEARCH UNIT

Lincoln College

A REGIONAL ANALYSIS OF FUTURE SHEEP PRODUCTION IN NEW ZEALAND

by

R. W. M. JOHNSON

Research Report No. 63

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THE AGRICULTURAL ECONOMICS RESEARCH UNIT

THE Unit was established in 1962 at Lincoln College with an annual grant from the Department of Scientific and Industrial Research. This general grant has been supplemented by grants from the Wool Research Organisation and other bodies for specific research projects.

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A REGIONAL ANALYSIS OF FUTURE SHEEP PRODUCTION IN NEW ZEALAND - AN APPLICATION OF SPATIAL LINEAR PROGRAMMING

by

R. W. M. Johnson

Agricultural Economics Research Unit Research Report No. 63

PREFACE

In this Research Report, Dr Johnson sets out the details of the linear programming model of the New Zealand sheep industry which the Unit has developed in the last two years. The model is particularly useful for a normative study of the livestock economy of New Zealand, as its regional basis allows considerable depth of detail to be incorporated. The eight regions in the model are based on the classification of sheep breeding and fattening areas used by the New Zealand Meat & Wool Boards' Economic Service. Further work is under way to incorporate the dairy farming regions of the North Island.

The broad results of this research project indicate that sheep and beef enterprises are likely to be strictly competitive in the New Zealand sheep industry in the coming decade, and that further shifts in beef prices relative to wool prices particularly could bring about a marked alteration in the product mix emerging from New Zealand farms. These results are obtained by assuming that certain prices might prevail in the decade ahead, and hence do not indicate that such price levels would in fact come about. However, the relative increase in profitability of beef production in recent years does look as though it will continue and the results of this paper indicate the likely size of the national beef herd by the end of the 1970s.

We are grateful to the International Wool Secretariat for a grant toward the cost of this project, and to the New Zealand Meat & Wool Boards' Economic Service for supplementary information and advice on their farm surveys. The results presented here, however, in no way commit these two organisations and are published here on our own responsibility, as a contribution toward a better understanding of the structural dynamics of New Zealand agriculture.

B.P. Philpott

Lincoln College,
July, 1970

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A REGIONAL ANALYSIS OF FUTURE SHEEP PRODUCTION IN NEW ZEALAND*

INTRODUCTION

The study of supply has always interested agricultural economists. A complete understanding of the supply behaviour of farmers under different price situations is the basis of most teaching in agricultural economics and a necessity for all policy making in this area. And yet this textbook view of agricultural supply has always been difficult to quantify and apply to actual situations or in practice. The application of linear programming teachniques to this problem has now altered the measurement situation completely. Not only can the representative farm be analysed in a large number of price and factor supply situations but groups of different representative farms can be handled just as competently to obtain the correctly specified national response to a given change in prices and so on. A national industry can be divided into homogeneous regions, and regions can be further divided into numbers of farms, different types of farm and so on. In fact, linear programming is completely flexible as a tool of research in this field, as the appropriate specification of the firm, region or industry can be made for any number of different policy studies.

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* The author gratefully acknowledges the thought and effort put into the research project reported here by D. McClatchy and A. D. Meister.

One word of caution should be added to temper this enthusiasm for linear programming as a tool of research. The results of such a study as this do not purport to be a prognosis of what ought to be; this study is purely normative in nature and states what may happen if certain assumptions are made about resources available, price levels, and farmers' responses to changing price levels at the margin. In short, it is a study of normative supply from which policy makers and others will be able to draw certain broad conclusions about the effects of different export outcomes and national policies.

This report sets out the details of the linear programming model that has been developed in the Research Unit for the New Zealand sheep industry. The research work was started in response to a request from the International Wool Secretariat for estimates of New Zealand wool supplies in 1980. Preliminary study showed that the problem was amenable to the linear programming approach, and that the regional basis of an aggregate model could be readily identified. In the event, the New Zealand sheep industry was divided into eight fairly homogeneous producing regions based on the classification of farm regions used by the Economic Service of the New Zealand Meat and Wool Boards. Within the regions a total of 33 separate enterprises were identified as having a possible influence on the national output of wool. The information on these enterprises and regions was assembled in the usual linear programming tableau and then used to predict wool supplies in 1980.

In the following pages, the details of the model used are set out with appropriate discussion of the more agricultural aspects of each stage of formulation. The formal properties of the model are stated briefly for those interested, but the main purpose of this report is to set out the Unit's thinking on how to best take advantage of the potentialities of linear programming in the construction of normative supply models for New Zealand agriculture. Further work is continuing in this area in the Research Unit.

THE REGIONAL BASIS OF THE MODEL

The research objective in defining the regions within a model is to find homogeneous groups of farms which are likely to behave in a similar manner under changing economic circumstances. Within the region all farms should require the same kind of resources, get similar results from the use of the resources, and have similar profitability levels. For perfect representation, it would clearly be desirable to have every sheep farm entering the national model, but for practical purposes, such massive detail is reduced to manageable proportions by taking typical farms that represent quite a large group within the total number of farms.

The stratification of the New Zealand sheep industry into breeding and fattening country is an obvious way of defining homogeneous regions that differ in natural resources, farming systems and profitability, and these two divisions in turn can be split up according to alternative enterprises, topography and latitude. This discussion demonstrates why economic regions are unlikely to be found in regional groupings such as the provinces and counties of New Zealand - and in which classifications all farm data for New Zealand is collected and summarised - and why economic regions must be based on sound resource and farm system bases.

The requirements for a satisfactory regional grouping and source of data are met by the surveys of sheep farms carried out by the New Zealand Meat and Wool Boards' Economic Service. They recognise eight different farming system regions covering 95 per cent of all sheep in the country and have systematically collected data on this basis for a good number of years (from 1958/59 season in fact). Clearly if such survey material is to be used for national prediction work it must also have a satisfactory sampling framework. This aspect is discussed in the next section of this Report.

The regional classification used by the Economic Service is described by them as follows:*

1. High country, South Island (Class 1 and 2S):

   Properties situated at high altitude, where the risk of snow loss is usually involved, and where carrying capacity is low, averaging about 5 acres to the sheep. The cover is principally native tussock, and wool is by far the most important source of revenue - 75 per cent or more in most cases. This type of farming has no counterpart in the North Island.

2. Foothill country, South Island (Class 3S):

   The name is almost self-explanatory. Whereas Merinos and halfbreds predominate on the high country, Corriedales, halfbreds and threequarter-breds comprise the sheep flocks of the foothills. Carrying capacity is about 1 sheep to the acre. Wool is very important, as are sales of store sheep and cast-for-age ewes. Cattle play a minor role.

3. Hard hill country, North Island (Class 2N):

   On this type of country and on all the remaining classes, the Romney (or Romney cross) is the only significant breed of sheep. In topography the hard hill country of the North Island is not so different from the South Island foothills, but the rainfall is higher, the winter is shorter and less severe, and cattle occupy a much more important place in the farm economy.

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* W.L. Keen and N.G. Gow, "Financial Analysis of New Zealand Sheep Farms", Bulletin No.12, December 1963. New Zealand Meat & Wool Boards' Economic Service, Wellington.

Carrying capacity is 1 to 2 sheep to the acre, plus cattle to the general order of 1 beast to 8 sheep. Wool accounts for just on half the revenue while the balance is derived from sales of breeding ewes, store sheep and cattle.

4. Hill country, North Island (Class 3N):

Easier hill country than the preceding class and usually smaller holdings, carrying 2 or 3 sheep to the acre with a higher proportion of breeding ewes. Cattle again are an important adjunct, with a general average of 1 beast to 10 sheep. Sales of wool have been slightly more important in recent years than sales of sheep and cattle. As a result of aerial top-dressing much of the surplus stock (other than breeding ewes and heifers) is now turned off in fat or forward condition, for example wether lambs and steers.

5. Fattening-breeding farms, South Island (Class 4Se):

These are fat-lamb farms of a rather extensive type, not on the most fertile land, averaging $2\frac{1}{2}$ sheep to the acre, and breeding most or all of their ewe replacements rather than buying them in. The country varies from flat to rolling hills; in some districts irrigation is undertaken; and special crops are grown for fattening lambs and for winter feed. In some years wool income takes second place to sales of fat sheep and lambs. Cattle are not important.

6. Intensive fat-lamb farms, North Island (Class 4N):

These farms represent grassland farming par excellence. They are on land of high fertility, either natural or induced, in relatively warm parts of the Island, mostly with a reliable rainfall. Carrying capacity is high, averaging nearly 4 sheep to the acre and occasionally reaching 6. Breeding ewes are nearly always bought in either at the 2-tooth stage or else as 4, 5 or 6 year ewes which are eventually disposed of as fats to the works. Cattle are usually bought in and fattened. The wool production enterprise definitely takes second place to the fattening enterprise.

7. Intensive fat-lamb farms, South Island (Class 4Si):

This class is in many respects similar to the North Island fat-lamb farm; the main differences are that - (i) in the South Island grass cannot be relied on so completely as in the North, and some feed crops are necessary, (ii) more breeding of own ewe replacements is done, (iii) cattle fattening is insignificant, (iv) carrying capacity is slightly higher, at an average of $4\frac{1}{2}$ sheep to the acre, reaching 6 quite frequently, (v) cash cropping is becoming an increasingly significant part of farm income. Wool production is regarded as a sideline activity, at any rate as far as the farm management policy is concerned.

8. Mixed fattening farms, South Island (Class 5S):

These are sheep farms where a large proportion of the income (though less than half) is derived from sources other than sheep or beef cattle. In Canterbury, which is the home of the mixed-fat-lamb farm, the main sources of this non-pastoral income are grains and small seeds. Although situated on good land, these farms carry only a moderate number of sheep to the acre (2 to 3) because of the relatively large area devoted to grain, root crops and seeds.

It can be seen that the South Island regions defined by the Economic Service do in fact approximate to fairly definite geographic areas, but in the North Island the classification is strictly stratified by farm type and no geographic boundaries could possibly be identified. This makes the researcher dependent on the Economic Service as the sole source of information, but does meet the research objectives laid down at the beginning of this section.

THE SAMPLING FRAMEWORK

At the time this research project commenced, the Economic Service survey had been completed up to the 1965/66 season. This gave sheep numbers as at June 30, 1966 in the sample, and provided the basis for all subsequent calculations and projections. Table I shows the distribution of the sample farms in 1965/66 among the economic regions cross-classified by geographic regions. A total of 527 farms was surveyed, with 125 farms from North Island hill country but only 26 farms from South Island mixed farming areas.

The weights or numbers of farms in the sampling frame given by Keen & Gow has been changed in recent publications from the Economic Service and are now presumably out-of-date. In this work, the 1966/67 weights are employed for raising all sample totals to national sheep flock figures.* For projection work, the researcher needs to be satisfied that the aggregate performance over all regions can be predicted from the sample data.

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* As given in "Sheep Farm Survey 1966/67", Publication No. 1443, November 1968, New Zealand Meat and Wool Boards' Economic Service, Wellington.

TABLE I Regional and Geographic Distribution of Economic Service Sample in 1965/66

Class of Farm	North Island						Class Totals
	North Auckland	South Auckland	Gisborne	Hawke's Bay	Wairarapa	West Coast	
2N	5	6	16	14	13	3	57
3N	16	40	15	25	8	21	125
4N	13	37	-	29	6	33	118
Region Totals	34	83	31	68	27	57	300

Class of Farm	South Island				Class Totals
	Marlborough	Canterbury	Otago	Southland	
1 & 2S	4	12	14	-	32
3S	7	31	3	-	41
4Se	2	29	22	8	61
4Si	-	3	17	47	67
5S	1	24	1	-	26
Region Totals	14	100	58	55	227
				All Classes	527

The main criteria of efficiency in raising the sample data to national totals is the estimate of the national flock of sheep. A satisfactory test of the criteria in turn would be that the national flock could be predicted over a period of years and not for just one year. In a perfect world it would be desirable to know the national numbers of farms within each economic region for every year, but in this test it is accepted that the 1966/67 estimate of the weights provided by the Economic Service is satisfactory for the years concerned, i.e. June 1964 to June 1968.

A further point that should be mentioned in passing is that the Economic Service sample is, in principle, re-drawn every year. In fact many farms do stay in the sample year after year, but all replacements must be drawn with due regard to the random nature of the sample. For this reason, the sample at the end of one season is not the same sample as that taken for the beginning of the next season. The researcher can thus calculate how much stock increase there has been on a homogeneous sample of farms for one season, or he can regard each end-of-season sample as a random drawing from the national population of sheep farms and regard the raised total as the correct estimate of the national sheep flock. In the example given below, both calculations are shown.

The raising formula to be used can be written as follows:

$$N = \sum n_i \; s_i$$

where N = a national total, say sheep numbers

n_i = the class weight, say number of farms per class

s_i = the class characteristic, say sheep per farm.

Table 2 shows the estimates of the national flock obtained from using this raising procedure compared with the actual national

TABLE 2

Estimates of National Flock from Economic Service Sample

Date of Sample	Estimated Sheep on Sheep Farms	Estimated National Flock	Actual National Flock
1.7.64	49.321	51.787	51.291
30.6.65	51.813	54.403	53.747
1.7.65	51.502	54.077	53.747
30.6.66	54.484	57.208	57.343
1.7.66	54.806	57.546	57.343
30.6.67	57.709	60.594	60.029
1.7.67	56.822	59.663	60.029
30.6.68	57.677	60.561	60.473

flock size for the beginning and end of the 1964/65, 1965/66, 1966/67 and 1967/68 seasons. It is assumed throughout that the Economic Service sample represents 95 per cent of all sheep on farms in New Zealand. The remaining sheep are located on "non-sheep" farms.

It is clear from Table 2 that the 1966/67 weights provided by the Economic Service are entirely satisfactory for the period analysed. Movements in the sample flock size can be effectively used to predict national changes in flock numbers and by implication other characteristics of the sample will be just as well-behaved.

For the national total of beef cattle the January 31st actual totals must first be converted to June 30th totals to allow for slaughter of stock in the intervening period. It is assumed without a great deal of concrete evidence that 50 per cent of all cattle slaughtered from January 31st to June 30th are drawn from the national beef herd. The following data show the estimated national beef herd as at 30 June derived from Farm Production Statistics alongside the estimate of the national beef herd derived from the Economic Service sample using the same weights as before and assuming that 90 per cent of all beef cattle are located on sheep farms.

	National Beef Cattle Total	Raised Sample Estimate of Total Beef Cattle
June 30 1965	3.306 m.	3.496 m.
June 30 1966	3.492	3.678
June 30 1967	3.860	3.977
June 30 1968	4.116	4.088

These results are not as accurate as those obtained for the national sheep flock but they do indicate that the cattle numbers on the sample farms show a reasonable correlation with national trends, given the unknown quantity of beef cattle slaughtered in the autumn between the census of cattle and the June balance day of the Economic Service accounts.

THE CHOICE OF ENTERPRISES

The unit of analysis within each region is the representative farm. The properties of the representative farm are obtained from survey data and do not, of course, represent any specific individual farm. In this kind of analysis it is assumed that the representative farm will respond to price changes in a way consistent with the majority of farms which it represents.

In this research project the basic objective was to isolate enterprises which were competing for the same set of resources as wool, and to design the analysis accordingly. Complementary enterprises should be grouped together in a suitable way and the formal activities in the model should be defined from enterprises which are substitutable in their demand for resources at the margin. In addition, the inclusion of too many enterprises would make the whole model unwieldy to handle even though such a procedure may represent reality more accurately. As with the choice of a suitable number of regions, a compromise must be made between errors of detail and other errors basic to the approach adopted.

To take account of the marginal nature of the substitution process, each enterprise activity is divided into two parts - one representing 1966 levels of each enterprise, and the second the extra level which can be chosen if net revenues and constraints in the future indicate that it is worthwhile. Each region already has a net revenue derived from present productive capacity. The extra level of each activity has a net revenue derived from the extra costs of introducing more units of that activity. When extra units of an activity are more profitable than the present level of another enterprise, the enterprise is sold up at disposal prices and the capital released re-invested.

Table 3 sets out the eleven enterprises which are considered in the model, and shows the particular regions in which each is found. There are thus 33 different choices of enterprise at the margin, changes in any one of which could alter the future supply of wool or any other important policy aggregate. 'Breed sheep' means that replacements are bred on the farm, and three wool types are recognised in different regions. 'Buy sheep' means that replacements are bought in; in the South Island this is considered as an even proportion of two-tooths and five-year ewes but in the North Island the buying-in policies are regarded as direct substitutes. Wethers are only found in South Island high country and are the usual dry flock many runholders find worthwhile. 'Breed cattle' and 'Buy cattle' differ in that one produces weaners and the other buys them in. No further variations

TABLE 3 Activity Mix Used in Model

Region	Breed Sheep Xbd	Breed Sheep Fine	Breed Sheep Med-fine	Buy Sheep Xbd	Buy Sheep Med-fine	Buy 5yr ewes N.I.	Buy 2th ewes N.I.	Run wethers	Breed Cattle	Buy Cattle	Crop
South Island:											
High Country		X						X	X		
Foothills			X						X	X	
Mixed hill & light land	X		X						X	X	X
Southland	X			X					X	X	X
Canterbury				X	X				X	X	X
North Island:											
Hard country	X								X		
Hill country	X						X		X	X	
Fattening country	X					X	X		X	X	X

in beef enterprises are considered. 'Crop' is a representative activity of all cropping possibilities aggregated together. Further details of each activity are discussed in the section on resource supplies.

In the high country of the South Island, a breeding flock of fine-woolled sheep has few alternatives. There is some scope for varying the proportion of dry sheep, and possibilities for breeding cattle. It is assumed throughout this paper that further increases in cattle in the future will be at the expense of sheep numbers and that the complementary phase of running both has already been passed.

In the foothill country of the South Island, breeding medium-fine wool sheep also predominates, but there is considerable potential for both breeding and finishing cattle. Some lambs are fattened and an allowance is made for this in net revenues. The mixed hill and light land country is similar to the foothill country, but crossbred sheep now become important, a higher proportion of lambs are fattened, and a small area is available for cash or forage crops.

In Southland, the choice is whether to breed crossbred wool sheep or to buy in mixed age crossbred replacements, to produce fat lambs along with both cattle alternatives, and a small crop area. Carrying capacities are much higher in this region and most surplus lambs fattened. In Canterbury cropping dominates the picture and it is assumed that a sheep breeding flock is not a realistic alternative. As wool prices change, farmers have the choice of shifting to fine woolled bought-in replacements, however, as well as a choice of cattle breeding and fattening.

In the North Island, cattle are frequently more important, and all sheep are crossbred. On hard hill country, the farmer is restricted to a choice of expanding his breeding flock or breeding cattle. In either case a considerable proportion of income comes from store stock and wool with very little finishing of stock being possible.

North Island hill country is easier in topography and climate than hard hill country, and farmers have a choice of breeding or buying their own replacements of both sheep and beef cattle. While stock can be turned off in fat or forward condition, the farming system is based entirely on grass and cropping is not a realistic alternative. On the best North Island pastoral country, fattening stock and dairy farming are the only real alternatives, plus cash cropping for specialised crops like maize, potatoes, peas and some grain. Breeding sheep and cattle replacements are included in the alternatives, but these are not likely to pay alongside buying replacement ewes at different ages and fattening weaner cattle. As already stressed, this model was designed to study possible changes in sheep numbers and wool output, hence the choice of activities in each region reflects our judgement of those enterprises which might be viable at differing export prices for lamb, wool and beef.

THE BASIC MODEL

It is useful to set out the objective function of the model and the restraints upon it first and then to discuss the details of the constraints in turn.

The maximisation objective is based on net revenues per unit of activity. Variable costs are deducted from all productive enterprises, so net revenue is defined as the residual return to all fixed factors of production. The activities entering the maximisation function may thus be summarised as:

(1) Maximise $Z = \sum_{a=1}^{z} \sum_{f=1}^{y^a} x_f^a \cdot c_f^a$

a = 1, 2......z farm regions,

f = 1, 2...... y^a farming activities,

x_f^a = level of f^{th} activity in a^{th} region,

c_f^a = net revenue of f^{th} activity in a^{th} region.

The maximisation function is subject to the following linear restraints:

(2) $x_f^a \geqq 0$ for all values of x_f^a,

(3) $B_d^a \geqq \sum_{f=1}^{y^a} x_f^a \cdot V_{df}^a$

d = 1, 2......w^a regional limiting resources

B_d^a = level of d^{th} limiting resource in a^{th} region

V_{df}^a = unit requirement of f^{th} activity in a^{th} region for d^{th} resource.

(4) $K_g \geqq \sum_{a=1}^{z} \sum_{f=1}^{y^a} x_f^a \cdot r_{gf}^a$

g = 1, 2......q interregional limiting resources

K_g = $K_1 K_2 \ldots\ldots K_q$ national resources

r_{gf}^a = unit requirement of f^{th} activity in the a^{th} region for the g^{th} national resource.

The activities entering the model are the typical additively separable enterprises which are found or might be found in each region. Each region is represented by an average farm which incorporates the range of productive activities found in each region. Resource availabilities and activity requirements are estimated on a per farm basis and the following identity shows how the regional resource limitations are arranged:

(5) $$B_d^a = N^a \cdot D_d^a$$

where N^a = the number of farms in region a,

D_d^a = the availability of the d^{th} resource on the average farm in the a^{th} region.

RESOURCE SUPPLIES

Each region in the model is self-contained as far as land, labour and capital are concerned, but the possibility of livestock transfers between regions requires inter-regional constraints to be adequately specified as well. Since the regional restraints are all similar they are discussed together in what follows.

The land resource is measured in terms of ewe equivalents of carrying capacity.* Present carrying capacity in each region is obtained from the sample farms for the season 1965/66 by dividing the grazing area per farm by the number of ewe equivalents carried per farm as follows:

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* See I.E. Coop "The Ewe Equivalent System", New Zealand Agricultural Science, Vol. 3, No. 1, 1965.

Region	Grazing Area per farm	Ewe Equivalents per farm	Carrying Capacity
1 & 2S	29,446	6,770	0.23
3S	3,538	3,318	0.94
4Se	873	2,425	2.77
4Si	323	1,781	5.50
5S	313	1,254	4.00
2N	1,843	4,630	2.51
3N	794	2,898	3.64
4N	371	2,040	5.50

To obtain the total area in the model and the total carrying capacity in all regions, crop areas are assumed to have the same carrying capacities as grazing areas. In the sample farms, total area is the sum of these and is called effective area, hence the total effective area in the model is obtained as follows:

Region	Effective area per farm	No. of farms	Total Area
1 & 2S	29,446 ac.	355	10.453 m. ac.
3S	3,538	908	3.213
4Se	873	2,464	2.151
4Si	352	4,284	1.508
5S	536	2,306	1.236
2N	1,843	2,226	4.102
3N	794	5,458	4.333
4N	397	6,407	2.543
		24,408	29.539

Total carrying capacity in 1966 in terms of ewe equivalents, can be calculated from the effective area per farm and present carrying capacity per acre weighted by the number of farms in each region. Total carrying capacity in any projection year depends on the assumptions made on productivity increases.

For the projections to 1979/80, each regional carrying capacity per acre was considered separately. In the light of the recommendations of the Agricultural Development Conference, the highest rates of increase in land productivity are likely to be found in the hill-country regions of both islands where aerial top-dressing and stocking techniques have the greatest potential. Thus in Regions 3S, 4Se, 2N and 3N, the rate of increase in carrying capacity could approach 4 per cent per year, hence projections were made on this basis and then rounded slightly. The more highly improved regions were judged to have much lower rates of increase, generally between 1.5 and 2.5 per cent per year. The South Island high country region at present carries 0.23 ewe equivalents per effective acre; this was allowed to rise to 0.25 EE/acre. The two levels of per acre carrying capacities and the implied rate of increase within each region were as follows:-

Region	Carrying Capacities per Acre		Implied Rate of Increase
	1966	1979	
1 & 2S	0.23	0.25	0.7 per cent
3S	0.94	1.50	3.7
4Se	2.77	4.32	3.5
4Si	5.50	6.50	1.4
5S	4.00	5.50	2.5
2N	2.51	4.00	3.6
3N	3.64	6.00	3.9
4N	5.50	7.00	1.9

On this basis there were 64.675 million ewe equivalents on the 24,408 farms as at June 1966, and there will be 93.532 m. ewe equivalents on the farms in June 1979. Thus the overall rate of increase in the land resource through increased productivity in the period is equivalent to 2.8 per cent per year.

The supply of labour is not formally constrained in the model. It is assumed that present labour supplies are adequate to cope with the potential increase in production, and in the case of a swing to beef production, some of the present labour force will no longer be required. This enters the marginal beef activities as a saving in the calculation of net revenues.

The increase in land productivity will require a continuing supply of new capital. In addition to this, the model is designed to make available, if necessary, all the capital locked up in existing plant and livestock. Thus the total supply of capital is made up as follows:

(a) External borrowing from lending institutions etc.,

plus (b) Internally generated farm profits

plus (c) Sale of existing plant and machinery and stock at depressed market rates; in an aggregate model of the kind outlined here any reduction of an existing activity would mean that the region as a whole would want to quit assets at give-away prices.

If an activity comes into the solution at its present level, all of (c) above simply cancels out; if an existing activity does not enter the solution, so much extra capital is made available at the depressed unit price level. Extra levels of activities generally have high capital requirements and this will mainly be financed out of borrowings and plough-back, although some small sums could come through from rejected activities in the way described.

Total capital supply for each region was therefore calculated as the value of existing liquid assets plus $2,500 per year per farm, which was the average level of capital expenditure on sheep farms in the Government Statistician's survey of Capital Expenditure on Farms in 1965/66. Regional total supplies of capital are as follows:

1 & 2S	$ 26.420 m.	5S	$ 96.959 m.
3S	52.047	2N	172.947
4Se	120.953	3N	314.074
4Si	183.592	4N	308.490

Other regional constraints concern the control of present stock and crop capacities in the model, and the potential limits of given stock and crop policies in each region. As already indicated each activity enters the model at two levels, present and extra. The objective in making this distinction was to isolate the marginal changes farmers could make in the coming decade given their present investment position. The present level of an activity has a net revenue based on current gross returns and direct costs. The extra level of the activity has a net revenue based on both current and capital costs of bringing more units of the activity on to the farm. To achieve this tripping effect in the solution requires constraints on all present level activities so that sheep numbers, cattle numbers and the crop area do not exceed the raised totals of these categories as at June 1966.

In the model, the sheep and cattle constraints are expressed in per head terms and the present capacity crop area in acres. The present resource supplies are as follows:

Region	Sheep	Cattle	Crop
1 & 2S	2.490 m.	0.049 m.	-
3S	2.856	0.124	-
4Se	6.231	0.163	0.087 m.ac.
4Si	7.693	0.120	0.050
5S	3.000	0.051	0.173
2N	7.512	0.962	-
3N	13.208	1.119	-
4N	11.488	0.756	0.085

The potential level of cropping in the four regions concerned is determined by physical factors such as topography, fertility maintenance and weed control, and soil conservation principles. The choice of the absolute limit on cropping in a region is fairly arbitrary with the present concentration on pastoral farming, hence the following limits should not be taken too seriously. In addition to the actual physical limit on cropping, export considerations will seriously limit crop expansion as well. It is assumed that the present area of 395,000 acres could only expand to 460,000 acres at present prices, and that net revenue will fall 20 per cent for any expansion up to 700,000 acres. From this area to 1,641,000 acres, the physical limit, net revenue is assumed to fall by another 20 per cent for export disposal reasons. The regional totals are:

Region	Existing Crop Area (1)	Extra (2)	Extra (3)	Maximum Potential (4)
4Se	.087 m.acs	0.100	0.150	0.215
4S	.050	0.060	0.100	0.302
5S	.173	0.200	0.300	0.742
4N	.085	0.100	0.150	0.382
	.395	0.460	0.700	1.641

Both maximum and minimum beef levels need to be considered. In the event of a swing to beef, beef cattle could never take over completely from sheep because in many areas soil type and drainage factors would lead to excessive pugging of pastures. The critical level of such a concentration of cattle is difficult to quantify, especially in the light of the many pure dairy-farming regions in New Zealand, hence the following limits are again more indicative than actual.

Minimum levels of beef stocking are relevant in all North Island districts where beef cattle play a part in pasture and weed control. The levels chosen indicate the percentage of beef cattle required in terms of total ewe equivalents.

Region	1 & 2S	3S	4Se	4Si	5S	2N	3N	4N
Max. Cattle	65	75	90	90	-	80	80	-
Min. Cattle	-	-	-	-	-	15	10	-

As an illustration of the intra-regional constraints in the model, Table 4 shows the programming tableau for Region 4N, fattening country in the North Island.

Inter-regional constraints are required to control stock movements between regions and the rate of growth of the national beef breeding herd. The necessity for these constraints was the major reason for combining all regions into a single national model, rather than programming each separately. It is necessary to ensure that net sales of various classes of store stock from all regions is balanced by net purchases. For example, every farmer in the country could not run breeding cows and sell weaners, some farmers must carry out the fattening process, and vice versa.

It was assumed that apart from stud stock, transport costs

Table 4 Intra-Regional Constraints in N.I. Fattening Region

4N	C_j*	Sheep Breeding 1	Sheep Breeding 2	Sheep Buying A 1	Sheep Buying A 2	Sheep Buying B 1	Sheep Buying B 2	Cattle Breeding 1	Cattle Breeding 2	Cattle Buying 1	Cattle Buying 2	Cropping 1	Cropping 2	Cropping 3	Cropping 4	Dairying 2
		6.867	6.164	5.272	4.674	5.902	5.304	33.849	30.059	44.769	43.169	50.0	43.6	35.0	25.0	62.030
	b_i															
Land	17.8 ≥ m. EE	1.172	1.172	1.016	1.016	1.016	1.016	6.671	6.671	4.00	4.00	7.0	7.0	7.0	7.0	7.90
Sheep Present Capacity	11.488 m. hd ≥	1.28		1.02		1.02										
Cattle Present Capacity	0.756 ≥ m. hd							1.181		1.00						
Crop Present Capacity 1	0.085 ≥ m. ac											1.0				
Max. Crop 2	0.1 ≥ m. ac											1.0	1.0			
Max. Crop 3	0.15 ≥ m. ac											1.0	1.0	1.0		
Max. Crop 4	0.302 ≥ m. ac											1.0	1.0	1.0	1.0	
Capital Supply	308.49 m. $ ≥	6.14	12.21	4.98	10.47	4.98	10.47	80.36	146.5	60.0	110.0	20.0	90.0	90.0	90.0	277.0

* 1968/69 Prices

would always rule out the transfer of store stock between islands, but that transfer between all regions in each island was feasible. Hence the reconciliation rows in the model have to be duplicated to cover both islands. The reconciliations include two-tooth and five-year ewe rows in the North Island, and a single draft-ewe row in the South Island. The latter is assumed to be made up from equal numbers of two-tooths and five-year ewes. A store cattle reconciliation row is also required for each island.

The store ewe rows are treated as equalities, and in North Island hill country both breeding and buying of two-tooth ewes can enter the solution together. In the case of cattle, an outside source of beef stores is available in the form of dairy-bred calves, hence the constraint takes the form of a maxima, with the estimated upper feasible level of dairy calf supply in the initial availability column. A slightly higher unit net revenue for fattening as opposed to breeding cattle forces the breeding function on to poorer country and hence effectively removes all store stock available. Most regions have the possibility of both breeding and fattening cattle as Table 5 shows.

The maximum number of beef breeding cows which will be available in the projection year enters the model at this point as a constraint on both islands. This is a severe restriction on the expansion of the sheep industry in New Zealand as a study of the physical coefficients of reproduction demonstrates. If the following equation shows the rate of growth of the breeding herd of beef cows,

$$K_t = (1 - a)K_{t-1} + b\,K_{t-2}$$

where K_t = stock of breeding cows in year t,

a = annual culling rate of breeding cows,

and b = the replacement rate of heifers,

then the following table shows the possible percentage rate of growth

TABLE 5 Inter-Regional Constraints

+ : Use of an activity

- : Supply of an activity

		1 + 2S	3S	4Si	4Se	5S	2N	3N	4N
N.I. Store Beef Reconciliation	+ ≥						-	- +	- +
S.I. Store Beef Reconciliation	+ ≥	-	- +	- +	- +	- +			
N.I. 2th Ewe Reconciliation	0 =						-	- +	+
N.I. 5yr Ewe Reconciliation	0 =						-	-	+
S.I. Ewe Reconciliation	0 =		-	+		+			
1 & 2S Wether Reconciliation	0 =	- +							
N.I. Breeding cow max.	+ ≥						+	+	+
S.I. Breeding cow max.	+ ≥	+	+	+	+	+			

of the national breeding herd with various values of a and b, when K_t = 1.1 m. cows in January 1966.

		1	2	3	4	5
1. Herd replacement rate (deaths & culling)	= a	20	20	20	20	15
2. Calving rate	)	80	80	80	80	80
3. Young female replacement stock deaths	) = b	3	3	3	3	3
4. Heifers suitable for retaining as replacements	)	30	25	20	10	20
5. 1979/80 stock of cows (m.)		2.25	2.70	3.21	4.48	5.17
6. Percentage growth permitted		5.6	7.1	8.6	11.4	12.7

On a long-term basis it appears unlikely that a rate of more than 7 per cent could be sustained for any period, hence in most of the work with the model the New Zealand maxima for beef cows in 1979/80 has been set at 2.6 million. In some cases the 8.6 per cent growth rate has been examined (3.2 m. cows in 1979/80) and some of the 1979/80 projections incorporating these results and given later. Since the maxima has to be divided between the two islands, the limit in the North Island is 2.08 m. cows and that in the South Island 0.52 m. cows in 1979/80 (a ratio of 4 : 1). For the target of 3.2 m. cows, the figures are 2.56 and 0.64 respectively.

Table 5 sets out the inter-regional basis of the model. In addition to the constraints already described, the table shows a store wether reconciliation row for the South Island high country region 1 & 2S. This constraint is to ensure that a minimum number of dry sheep enter the solution whether they are profitable or not. This level is set at 1 wether for every 2 ewes, and in addition an upper limit is set at 1 wether to every 1.25 ewes in the solution.

THE PRICING FRAMEWORK

In setting up the model, it was tested with average prices of the 1961-66 period, and the behaviour of the respective activities analysed for irrational choice of enterprise. In general, dairy farm and cropping net revenues tended to dominate all other activities up to the constraints provided. Tighter constraints were perhaps needed to reflect the drudgery and social status of dairy farming in sheep areas and the risk factor in crop areas. In the present report, however, dairy farming has been dropped from most of the analysis but cropping left in at the levels indicated. With the crop constraints totalling 700,000 acres, the error in predicting livestock numbers is fairly small, as 300,000 extra crop acres would reduce expected sheep numbers by 2.1 m. at the outside, and this might be quite realistic at certain price outcomes.

The results discussed in this report were obtained with a broad range of expected prices for each activity so that the reader and/or policy maker can make interpolations of his own. The basis of the prices chosen was a list of 1968/69 season export prices for main commodities. In the light of variations in export prices since 1961, and taking devaluation into account specifically, each commodity was given a high and low price expectation for the 1970s. Table 6 summarises these assumptions and the levels chosen. It should be noted that these are export values and all internally generated prices like those of store stock, grades of beef and so on have to be derived on a proportional basis in the light of local market knowledge.

The high and low price levels for products in Table 6 are actual prices expected in the 1970s and are not deflated in any way. Some inflation has been allowed for in estimating the expected requirements of the marginal component of each activity pair. Thus future capital investment could be said to be valued at average prices for the 1970s. As already pointed out, productivity increases have been assumed in sheep farming and beef farming, as well as allowing for an overall lower labour requirement in beef farming.

TABLE 6 The Price Assumptions

Commodity		Average 1961-66	Range 1961-66	Actual 1968-69	High 1979	Low 1979
Wool(cents per lb)						
Fine	(56-64's)	39.0	34.7-48.4	40.2	50.0	33.0
Medium	(50-56's)	39.5	35.9-49.5	35.7	48.0	29.0
Coarse	(48-50's & under)	35.1	21.0-44.5	25.8	42.0	22.0
Sheep Meat* (cents/lb)						
Lamb	(30 lb)	15.0	11.6-18.9	18.2	20.0	12.0
Mutton	(50 lb)	5.0	3.9- 7.7	5.4	7.0	4.0
Beef Meat (cents/lb)						
Heifer	S.I.	12.75	13.2-18.0	17.5	20.0	14.0
	N.I.	13.25				
Ox	S.I.	12.95	14.4-18.6	18.0	21.0	15.0
	N.I.	13.40				

*Note: Sheep meat prices include wool pull.

In calculating the net revenue of each marginal activity, the interest on capital costs at mid-decade prices is deducted. In so far as variable costs in the model are slightly higher than 1966 levels, all net revenues are also expressed in average prices for the 1970s. Since the price squeeze is likely to affect most products about equally, these allowances do not affect the solution values very much. Finally, disposal values for liquid capital assets are also valued at expected mid 1970 prices.

NET REVENUES OF ENTERPRISES

It is not possible to set out all the calculations for net revenues used in the projections, but the methodology can be illustrated by sample budgets and a discussion of physical coefficients, assumed in different regions. In the following budgets the derivation of existing net revenues per unit of activity is shown first and then the steps shown to obtain net revenue at the margin. Variable costs associated with each enterprise are deducted from gross revenue to obtain unit net revenue. All animal activities are expressed in per head terms and all crop activities are expressed in per acre terms. Stock reconciliations were worked out for each productive enterprise and then reduced to a one ewe (or one cow) plus replacements basis.

The following budgets show calculations for sheep breeding and cattle breeding on hard hill country in the North Island and cattle fattening on North Island fattening country by way of example of the methodology followed:

Hill Country, North Island (2N)

1. Sheep Breeding at 1968/69 Prices

One Unit of Activity is
1 ewe
.425 ewe hoggets
.03 rams
1.455 head

Revenues (per ewe unit)

			$
Wool (Xbd)	15.702 lbs	@ 23.31 cents net	3.660
Cull 2T ewes	.106	@ $7.05	.747
Cull 5 yr ewes	.178	@ $5.05	.899
Works ewes	.068	@ $2.535	.172
Fat & Store lambs	.42	@ $4.496	1.888
			7.366

Variable Costs

Shearing, stock health, ram replacements

1 ewe	@ $0.70		.700
.425 hoggets	@ $0.45		.191
.03 rams	@ $14		.420
			1.311
		Net Revenue 1.	$6.055

Extra Costs

Livestock Replacements

1 ewe	@ $6.5	6.500
.425 ewe hoggets	@ $6.0	2.550
.03 ram	@ $36	1.080
		10.130

Capital Improvements

Woolshed $4500 per 2000 ewes		2.250
Yards & Fences $0.5 per ewe		10.500
Hayshed $500 per 1000 ewes		0.500
		3.250
	Total Extra	13.380
	Interest @ 6%	0.803
	Net Revenue 1.	6.055
	less Interest	- .803
	Net Revenue 2.	$5.252

2. Cattle Breeding (2N) at 1968/69 Prices

One Unit of Activity is

1.000	breeding cow
.180	weaners female
.175	yearling female
.025	bull
1.380	

Revenues (per cow unit)

			$
Weaner	.620 @ $44.50 net		27.590
Cull cows	.117 @ $78.00 net		9.126
			36.716

Variable Costs

Breeding cow	1.0	@ $1.0 per year	1.000
Bulls	.025	@ $65 per head	1.625
Weaner heifers,	0.18	@ $1.7 per head	.306
			2.931
		Net Revenue 1	$33.785

Extra Costs

Livestock Purchases

1 cow	@ $95	95.00
.18 weaner female	@ $80	14.400
.175 yearling female	@ $95	16.625
.025 bulls	@ $360	9.000
		135.025

Capital Improvements

Cattle yards,	$1,500 per 100 head		15.000
Fences & water,	$1,000 per 100 head		10.000
Extra working capital,	$1,000 per 100 head		10.000
Hayshed	$ 500 per 200 head		2.500
			37.500
		Total Extra	172.500
		Interest at 6%	10.350
Labour saving component,	$2,000 per 400 head		5.000
		Net Revenue 1	33.785
		less Interest	-10.350
		plus Labour saved	+ 5.000
		Net Revenue 2	$28.435

3. Cattle Fattening 4N at 1968/69 Prices

One unit of Activity is
1.0 weaner bought

Revenues (per unit)		$
18 mths (550 lbs) fat cattle 970 @ $97.7 net		94.769
Variable Costs		
Running costs weaners 1.0 @ $0.7		.700
Buy weaners 1.0 @ $49.30		49.300
		50.000
	Net Revenue 1	$44.769
Extra Costs		
Livestock Purchase		
1.0 weaner @ $80		80.000
Capital Improvements		
Beef Yards	$1000 per 100 beasts	10.000
Fences & Water	$ 500 per 100 beasts	5.000
Extra Working Capital	$1000 per 100 beasts	10.000
Hayshed	$ 500 per 100 beasts	5.000
		30.000
	Total	110.000
	Interest at 6%	6.600
	Labour saving $2000 per 400 beasts	5.000
	Net Revenue 1	44.769
	less Interest	- 6.600
	plus Labour saved	+ 5.000
	Net Revenue 2	$43.169

Before discussing the complete range of physical coefficients used in livestock activities, it is appropriate to set out briefly how the crop and dairy activities were defined. The crop activity is based on an average acre of cash crops - wheat, barley and small seeds included. For Southland a 70 bushel wheat crop was the standard, with 45 bushels in 4Se, 60 bushels in 5S and 50 bushels in 4N. Fifteen dollars were generally allowed for variable costs to give net revenues of $75, $40, $65 and $50 respectively for the regions. The disposal value of cropping machinery was estimated at $15-$20 per acre and the capital requirement for an expanded crop acreage was set at $60-$90 per acre. A wheat price of $1.35 per bushel was used to calculate net revenues up to a crop area of 460,000 acres in the model, thereafter sales would have to be made on overseas markets and it was assumed that net revenues would fall by at least 20 per cent up to an acreage of 700,000. Between 395,000 acres, the present crop area in the regions, and 460,000 acres, the net revenue is reduced by the amount of the interest on extra capital, and from 460,000 to 700,000 by the interest charge and an allowance for reduced overseas earnings. Where the crop constraint was allowed to extend to the full potential crop area of 1.4 m. acres, a further 20 per cent fall in net revenues was assumed. The resulting set of net revenues are shown in Table 9.

The impact of introducing dairy farming into 4Si, 5S and 4N, was considered in some solutions. Since no dairy farming is found at present in these regions, the net revenue from an extra or marginal unit of a dairy activity only is required. It was assumed that a gross return per cow of $118 could be achieved with 300 lb butterfat/acre (at 32 cents per lb) and due allowance for surplus stock. Direct costs were estimated at $25 per cow, and capital costs at about $280 per cow. Taking interest at $17.22, and the extra labour requirement of dairying at $2,000 per 120 cows or $16.70 per cow, net revenue per unit of extra activity in dairying works out at $60 per acre. It was assumed that 1 cow was equal to 7.9 ewe equivalents where necessary.

Details of the physical and financial coefficients assumed for each representative farm or region for sheep farming are set out in Table 7. The physical coefficients determine the stock reconciliation

TABLE 7

Physical and Financial Coefficients for Sheep Farming

	1 & 2S	3S	4Se	4Si	5S	2N	3N	4N
Lambing (%)	75	94	108	115	105	85	93	100
Annual culling rate (%)	2	5	4	5	3	4	4	2
Annual death rate (%)	6	5	4	5	4	6	5	4
E.E. per unit	1.42	1.34	1.17	1.18	1.02	1.28	1.29	1.17
Wool per ewe* (lbs)	8	9	11	11	11	11	11.5	11
Wool per ram (lbs)	12	12	10	10		15	15	10
Wool per hogget (lbs)	6.5	7	8	7		8	8	8
Wool per two-tooth (lbs)	10				8.5			
Disposal value per ewe ($)	5	5	4.5	4.5	4.5	4.5	4.5	4.5
Disposal value per hgt ($)	4	4	4	4		4	4	4
Disposal value per ram ($)	24	24	24	24	24	24	24	24
Buying price per ewe ($)	7	7	6.5	6.5	6.5	6.5	6.5	6.5
Buying price per hgt ($)	6	6	6	6	6	6	6	6
Buying price per ram ($)	36	36	36	36	36	36	36	36

* Wool is measured on an on-farm shorn basis; slipe wool and wool on skins is estimated separately when required.

pattern in each activity from which shorn wool weights, surplus stock and replacement needs are derived. When the particular set of expected prices is decided, the net revenue levels can be worked out as shown in the budgets above. The reader should be able to work out for himself the steps shown in the budget for North Island hard hill sheep country from the data provided in Table 7, using a 2000 ewe flock as the basis of calculations. Disposal values of stock are required for the capital resource supply calculation and for the intra-regional capital coefficients on present level activities in the tableau. Buying prices of stock are required for the intra-regional capital coefficients for extra levels of activities in the tableau. Table 4 shows these coefficients for Region 4N, fattening country in the North Island.

It should be noted that these capital values of stock do not change when expected product prices are changed. In a more detailed model or where the objective under investigation warrants the extra work, buying prices and disposal prices should be adjusted in line with expected product prices in each projection carried out.

Table 8 shows the physical and financial coefficients for beef enterprises for each region. The same remarks made on sheep enterprises apply to these coefficients as well. The capital coefficients for beef in Region 4N can be found in the appropriate columns of Table 4.

For each set of expected prices used in a projection, the whole set of net revenues must be re-calculated. As already set out in the section on the pricing framework, a direct forecast of price levels in the 1970s was not attempted in this research work; instead a set of low and high levels of expected prices for products was chosen and the behaviour of the model studied under different combinations of these. In addition, a few projections were run at average prices for 1968/69 as representing possible present expectations of farmers as to price levels in the 1970s.

TABLE 8

Physical and Financial Coefficients for Beef Farming

Beef Breeding		1 & 2S	3S	4Se	4Si	5S	2N	3N	4N
Calving	(%)	75	80	85	85	85	80	85	85
Years in herd		6	7	8	8	8	7	8	9
Annual culling rate	(%)	2	1	1	1	1	1	1	1
Annual death rate	(%)	6	3	1	1	1	5	8	8
Heifers added	(%)	20	16.5	13.8	13.8	13.8	17.5	17.2	15.6
Age of heifer to bull	(yrs)	3	2	2	2	2	3	3	2
E.E. per unit		10.45	8.05	7.25	7.82	6.68	7.45	7.43	6.67
Beef Fattening									
Propn sold 18 mths	(%)	-	48	99	99	99	-	48	99
Annual death rate	(%)	-	2	1	1	1	-	2	1
Weight at sale	(lbs)	-	550	550	550	550	-	600	550
E.E. per unit		-	4.17	5.00	5.00	4.00	-	4.17	4.00
Disposal value/cow	($)	60	65	60	60	60	65	65	65
Disposal value/heifer		60	65	60	60	60	65	65	-
Disposal value/bull		240	240	240	240	240	240	240	240
Disposal value/weaner		50	60	60	60	60	60	60	60
Buying price/cow		90	95	90	90	90	95	95	95
Buying price/heifer		80	95	80	80	80	95	95	-
Buying price/bull		360	360	360	360	360	360	360	360
Buying price/weaner		70	90	80	80	80	80	80	80

The complete set of net revenues required for a projection at 1968/69 prices are set out in Table 9. In some South Island regions two different activities based on the quality of wool are possible

TABLE 10

Net Revenues per Unit of Activity at "High Prices"
($ per unit)

	Sheep (1)	Breeding (2)		Sheep (1)	Buying (2)
1 & 2S (fine)	7.73	6.23		-	-
1 & 2S (wethers)	3.96	2.96		-	-
3S (med-fine)	9.83	8.97		-	-
4Se (med-fine)	9.84	9.08		-	-
4Se (Xbred)	9.90	9.14		-	-
4Si (Xbred)	10.28	9.50		8.48	7.83
5S (med-fine)	-	-		7.33	6.67
5S (Xbred)	-	-		7.64	6.98
2N (Xbred)	9.00	8.20		-	-
3N (Xbred)	10.32	9.52		7.95	7.32
4N (Xbred)	9.76	9.05	(5 yr)	7.59	6.99
			(2. T.)	8.42	7.82

	Beef Breeding (1)	Beef Breeding (2)	Beef Fattening (1)	Beef Fattening (2)
1 & 2S	49.31	39.70	-	-
3S	38.96	34.12	30.17	27.57
4Se	42.58	39.17	43.59	41.81
4Si	42.58	39.17	43.59	41.81
5S	42.58	39.17	43.59	41.81
2N	37.69	32.34	-	-
3N	37.26	31.91	40.23	37.63
4N	37.61	33.82	41.61	40.01

TABLE 11

Net Revenues per Unit of Activity at "Low Prices"
($ per Unit)

	Sheep Breeding* (1)	(2)	Sheep Buying (1)	(2)
1 & 2S (fine)	4.46	2.96	-	-
1 & 2S (wethers)	1.74	0.74	-	-
3S (med-fine)	5.60	4.74	-	-
4Se (med-fine)	5.28	4.52	-	-
4Se (Xbred)	4.77	4.01	-	-
4Si (Xbred)	5.09	4.32	3.59	2.94
5S (med-fine)	-	-	3.35	2.69
5S (Xbred)	-	-	3.19	2.53
2N (Xbred)	4.45	3.65	-	-
3N (Xbred)	5.52	4.72	3.34	2.70
4N (Xbred)	4.81	4.11	(3.16	3.56 (5 yr)
			(3.74	3.14 (2 T)

	Beef Breeding (1)	(2)	Beef Fattening (1)	(2)
1 & 2S	33.19	23.58	-	-
3S	26.92	21.97	21.83	19.23
4Se	30.55	27.14	33.50	31.72
4Si	30.55	27.14	33.50	31.72
5S	30.55	27.14	33.50	31.72
2N	26.91	21.56	-	-
3N	26.77	21.42	25.06	22.46
4N	27.06	23.28	31.69	30.09

* When wool is "high" and lamb is "low, and vice versa, a different set of net revenues is used in the model.

This completes the description of the methodology employed in building the model and the concluding section briefly sets out the main projection results that have been estimated.*

PROJECTIONS OF LIVESTOCK NUMBERS AND WOOL OUTPUT IN 1979/80

The broad approach adopted in this research project was to study the possible alternatives to wool production in the New Zealand sheep industry in the 1970s. The target year of 1979/80 was chosen to fit in with other projection work being carried out in the International Wool Secretariat. Sheep meat is a joint product with wool, but nevertheless considerable adjustment is possible within the industry in a 13 year period between the different meat and wool breeds of sheep This situation is reflected in the calculation of net revenues per unit of activity discussed immediately above, and in the range of results discussed shortly. In addition to the dual products of sheep, the New Zealand sheep industry is already in a position to economically produce beef meat from the same set of resources available to it with very minor adjustments. Historically, beef cattle had a complementary relationship to sheep on New Zealand farms because of the different pastoral habits and growth patterns. In the 1970s the

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* The main results have already been published in the following papers: "A Regional Projection Model of the New Zealand Sheep Industry", New Zealand Economic Papers (forthcoming), and "The Future Profitability of Beef Production in New Zealand", Paper to the N.Z. Institute of Agricultural Science, August, 1970.

industry can be expected to move completely into a substitution relationship between the two classes of stock as beef product prices improve relative to sheep product prices. It is this factor which provides great flexibility to the industry as a whole in the coming years and which, incidentally, allows the model described in these pages to work as well.

It must still be realised, however, that the results given in this section are only the product of the assumptions that have been made. A linear programming model only provides a normative ("what ought to be") view of the economy and results need to be interpreted with due regard for the method by which they were obtained. In particular, the model assumes that farmers are profit maximisers and will produce what pays best irrespective of other considerations. It assumes there is no demand relationship interacting with the supply of products at whatever level projected. It assumes farmers are aware of the real profitability of each enterprise at the margin, and that in 13 years they can make all the necessary adjustments to their production plans and management to obtain the livestock proportions predicted. It is believed that all these assumptions are reasonable in the case of the New Zealand sheep industry.

As explained in an early section of this report, the regional approach to the problem in hand was chosen so as to obtain reliable predictions of national livestock totals. No results have therefore been presented for individual regions in the model as each of these is less reliable than the national aggregate prediction. In addition the North Island "regions" have no known geographic boundaries. It might also be useful to point out at this time that each region is a self-contained producing area and the solution only seeks to find out what the best choice of enterprises should be within the region. The choice of enterprises is of course subject to the inter-regional livestock constraints, but the net revenues set out in the last section are only comparable within regions.

The basis of the model is the sheep farming industry of New Zealand as defined by the Economic Service of the New Zealand Meat and Wool Boards. This covers 95 per cent of the sheep in the whole of New Zealand and 90 per cent of the beef cattle. To obtain national totals the projection totals should be multiplied up by the appropriate factors. In addition, the wool estimate is calculated on a shorn wool basis, and if the national output of greasy wool is required, then all wool projections should be raised by 5 per cent to obtain the equivalent national shorn wool aggregate and then raised by a further 15 per cent to obtain total greasy wool output, which includes slipe and skin wool.

The coefficients of the model were selected from the 1965/66 survey of sheep farmers carried out by the Economic Service and the national totals were based on sheep numbers as at June 1966 and wool output from these sheep, that is wool output for 1966/67. Beef cattle figures are based on January 1966 totals as in Farm Production Statistics. The projections are for the 13 year period from June 1966 to June 1979 so as to accurately predict wool output in the farming season of 1979/80. The beef cow projections are for January 1979 totals within the sheep industry. Total beef cattle numbers and outputs need to be calculated from the raised national total of beef cows by appropriate factors.

The kind of result the linear programming solution of the model gives can be seen in a discussion of projections at 1968/69 prices shown in Table 12. This set of projections was carried out at two levels of beef breeding potential and two levels of dairy beef potential. These maxima are shown at the top of the table. Underneath are shown the projected numbers of livestock, area of crop and output of wool consistent with the prices, coefficients and constraints in the model.

TABLE 12

Projections of Sheep Industry Aggregates in 1979 with "Expected" Prices equal to 1968/69 Season Levels

Beef Breeding Maxima (m)	2.6	3.2	2.6	3.2	1966
Dairy Beef Maxima (m)	.25	.25	.5	.5	Totals
Projected sheep nos. (m)	68.9	62.2	67.8	61.1	54.4
Projected beef cow nos. (m)	2.6	3.2	2.6	3.2	1.1
Projected Crop Area (ac)	.6	.6	.6	.6	.395
Projected Med. Fine Wool (m.lb)	118.6	115.4	118.8	113.9	95.9
Projected Xbred Wool (m.lb)	617.8	546.5	605.2	535.8	476.6
Total Wool	736.6	661.9	724.1	649.8	572.5

The last column shows the levels of these aggregates in the sheep farming sector as defined in 1966. It is clear that the 1968/69 set of prices favoured beef production over all forms of sheep production. If beef breeding potential is allowed to increase at a faster rate, sheep numbers drop from 68.9 m in 1979 to 62.2 m. If dairy bred calves increase to 500,000 from 250,000, then the number of sheep drops by 1.1 m to make room for them on farms. It will be noted that not all the available crop area is taken up but there is a considerable expansion from the present 395,000 acres to 600,000 acres. Accepting that the faster rate of expansion of beef production will be difficult to achieve, it would appear that if 1968/69 price ratios continue in the 1970s, then the national beef herd could expand at some 7 per cent and that sheep numbers and wool production will expand to 69 m sheep and 740 lbs of shorn wool, a rate of increase of 1.8 per cent per year.

There are a large number of permutations and combinations of high and low price expectations. Fifteen of these are presented in Table 13 to give the reader some idea of the range of results possible with the model. The first three rows show the price expectation with regard to the main three products of the industry. The system followed in the presentation is to study the effect of changing one product price at a time. The next two rows show the beef potential and dairy bred calf potentials and at the bottom a row indicates whether the dairying activities were introduced or not. The remaining totals are the same as for Table 12.

The broad results obtained with these prices is that HHH prices (beef, wool, lamb prices respectively) favour the sheep industry (1, 2,) and this result is not influenced by dairy bred calves. On the other hand the LLL solutions (12, 13, 14,) favour beef production up to the maximum permitted and sheep are displaced by dairy bred calves as in Table 12. Low prices for lamb alone (3, 4,) favour beef production almost to the limit, and low prices for both wool and lamb (5, 6,) bring beef up to its maximum again. Low prices for wool alone (7, 8,) also bring beef in at the maximum. Low prices for beef and wool (9,) and for beef alone (10,) both favour the sheep industry at the expense of beef, especially the latter projection. If beef and lamb are down, i. e. meat, this result also follows (11,).

Dairy farming at 32 cents for butterfat is highly competitive for good quality land in New Zealand and the last solution (15,) indicates that 850, 000 milking cows would displace mainly beef production at the HHH set of prices. At any other set of prices, more milking cows would enter the solution. It is not clear, of course, what would happen as the payout is reduced progressively from 32 cents/lb! There are clearly social and other economic reasons why dairy farming is concentrated in certain parts of New Zealand and not others, and at the present time any encroachment of dairy farming into traditional sheep farming areas seems most unlikely.

Crop activities only come into the solutions at the maximum 700,000 acres when two or more product prices are set at low expectation levels, but while projected levels are considerably above present crop levels, the general run of results indicates that fairly competitive price levels for crops were chosen in the first place.

There is also considerable variation in wool quality as lamb and wool prices interact in the projections. At low wool and lamb prices, the proportion of fine wool increases considerably, but if only lamb prices are low, the output of fine wool tends to be depressed. This is explained by the relatively favourable levels Crossbred wool has reached in the past, and the combination of good Crossbred wool prices with low schedule prices favours an expansion in Crossbred sheep.

TABLE 13 Projections of Sheep Industry Aggregates in

Projection No.	1	2	3	4	5	6
Beef Price Expectation	H	H	H	H	H	H
Wool Price Expectation	H	H	H	H	L	L
Lamb Price Expectation	H	H	L	L	L	L
Beef Breeding Maxima (m)	2.6	2.6	2.6	3.2	2.6	3.2
Dairy Beef Maxima (m)	.25	.5	.25	.25	.25	.25
Projected sheep nos. (m)	90.9	90.9	69.2	64.1	68.4	61.8
Projected beef cow nos.(m)	.67	.57	2.6	3.04	2.6	3.2
Projected crop area(m.ac)	.5	.5	.63	.63	.7	.7
Projected med-fine wool(m.lbs)	127.9	127.9	70.1	69.7	121.7	112.9
Projected Xbred wool (m.lbs)	855.9	855.9	681.6	625.6	605.7	545.9
Projected Total wool (m.lbs)	984.0	984.0	751.7	695.5	727.4	659.0
Dairy Enterprise (m.cows)	-	-	-	-	-	-

1979 at Different Expected Price Combinations

7	8	9	10	11	12	13	14	15
H	H	L	L	L	L	L	L	H
L	L	L	H	H	L	L	L	H
H	H	H	H	L	L	L	L	H
2.6	3.2	2.6	2.6	2.6	2.6	2.6	3.2	2.6
.25	.25	.25	.25	.25	.25	.5	.25	.25
68.9	62.3	83.1	92.3	88.4	68.5	67.4	62.0	83.5
2.6	3.2	1.29	.55	.83	2.6	2.6	3.2	.67
.65	.65	.65	.5	.65	.7	.7	.7	.5
116.7	112.5	133.7	135.0	88.7	121.8	119.1	112.5	127.9
617.1	552.8	754.8	860.6	872.0	610.4	600.8	547.1	770.7
733.9	665.5	888.6	995.7	960.7	732.3	720.0	659.7	898.7
-	-	-	-	-	-	-	-	.85

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