A DAIRY SUPPLY MODEL INCORPORATING

THE CONCEPT OF LIVESTOCK AS INVESTMENT INPUTS

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CHAPTER ONE

INTRODUCTION

The New Zealand dairy industry is an important contributor to the New Zealand economy.   The industry earns approximately 20 percent of New Zealand's export income from the sale of milk related products. It also earns a substantial proportion of the meat export income from surplus calves and cull cows.

The industry is organised on a cooperative basis with each farmer supplying milk (or cream) to his cooperative factory.   The factories process the milk into a variety of products which are sold locally, to the New Zealand Dairy Board, or, in a few special circumstances, directly overseas.   The export market dominates the industry, taking approximately 80 percent of butter production, 90 percent of cheese production, 90 percent of milk powder production and more than 99 percent of casein production /¯59_/*.

The New Zealand Dairy Board controls the export marketing of milk related products and some of the products from surplus calves.   The cooperative factories influence the Dairy Board through their representatives on the Board and the farmers control the factories through their shareholding in the factories.

The seasonal supply dairy farms, while scattered throughout NZ, tend to be concentrated in a few important regions.   For the purposes of study, the NZ Dairy Board separates New Zealand into 11 dairying regions.   Of these, 3 regions (Northland, South Auckland and Taranaki/ Western Uplands) contain approximately 60 percent of the dairy herds of 10 or more cows.

The study of supply relationships in agriculture is frought with many difficulties.   In Chapter Two, the difficulties and ·some of the methods that can be used to overcome them are discussed.   The chapter

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* The references are listed in the Bibliography.

includes a discussion of previous New Zealand dairy supply studies and studies of interest from other countries.

The theory of investment and its application to a dairy farmer are included in Chapter Two. Dairy cows are capital items used in the production of dairy products. As the prices of output and inputs change, the stock of capital (the herd) will change in size and composition. These changes are due to the effects of investment decisions. In the discussion, the basis for a model that can take account of the investment process in dairy cattle is outlined.

The Taranaki region is chosen for the study because the dairy farmers in the region tend to be specialised producers who produce little in the way of other products. This specialisation reduces the variability of the region and makes the region easier to model since the farmers have a narrower range of decisions to make. Further, Taranaki is one of New Zealand's major dairy farming regions and so changes in the region are of importance to the industry. Finally, the author of this study is familiar with the region and this familiarity was helpful in conceptualising the supply relationships. The homogeneity of the sample is increased by studying only the factory milk supply dairy farms. The data covers the period from 1963/64 to 1973/74 for the Taranaki/Western Uplands region and is supplied by the NZ Dairy Board, Farm Production Division. The changes that have occurred in the region over the period of the data and the prices used in the study are discussed in Chapter Three.

The New Zealand Dairy Board undertakes annual surveys of each dairy farming region in New Zealand. The purpose of the surveys is to gather information on many aspects of the dairy industry including the economics and efficiency of dairy farming in New Zealand. From the surveys, data on the average farm for each region, herd size and type of supply are published.

This information is extremely valuable as an historical record of changes in the industry but, as with all surveys, there is a delay from the period to which the information refers, to the time the information is published. In the case of the information on each region, most of the data is collected in one season, refers to the previous season and,

by the time the information is analysed and published, another season
has passed. Some of the information is made available within a
relatively short time but most of the information is at least two seasons
out of date. However, attempts have been made to rectify this
situation by questioning farmers about their production plans.

There still remains a need for the Dairy Board and the cooperative
factories to project future stock numbers and milk production in order
to organise marketing strategies and make investment plans. This study
is an attempt to develop a procedure that could be used to project
future dairy farm output, stock numbers and the level of inputs on a
regional basis. In the study, dairy farm output includes milkfat, cull
cows and surplus calves. The procedure used in the study attempts to
model a dairy farm production system and a dairy farmer decision process.
In modelling, the aim is to represent the actual situation in a form
that can be used to test the behaviour of the actual situation. In
this study, the actual situation is modelled mathematically. The model
is a simplified version of the actual situation and thus cannot be
expected to reproduce the full complexities of the actual situation.

The study assumes that a dairy farmer wishes to maximize his
profits over time, based on his expectations of future prices and
subject to production function constraints. It is further assumed that
over his planning horizon, the dairy farmer will envisage adjusting
stock numbers so that at the end of the planning horizon the farmer is
milking an 'optimum' number of cows. The year after the plan is made,
prices will have changed causing the farmer's expectations of future
prices to change. Thus the farmer will make a new plan with an
envisaged new 'optimum' number of cows.

The chapters on previous studies, investment theory and the
Taranaki/Western Uplands region form the basis for a model of a dairy
farm. The model consists of a dairy farm production system and a dairy
farmer decision process. The model and the assumptions upon which the
model is built, are described in Chapter Four.

The model is 'fitted' to data on the average factory milk supply
dairy farm in the Taranaki/Western Uplands region. The aim in 'fitting'
the model to the data, is to make the model predict the important

decisions made by the dairy farmer. The model is then used to make projections. The procedures used to estimate the parameters in the model, the results and evaluation of the model and the projections made outside the period for which data is available are discussed in Chapter Five.

Finally, the conclusions reached are discussed in Chapter Six. The chapter includes a discussion of the technique used and an evaluation of its applicability for further use. The results of the study are also discussed.

CHAPTER TWO

THE SUPPLY RELATIONSHIPS IN AGRICULTURE

The aims of this chapter are rather broad. The chapter aims to develop a supply model from the theory of the firm, to show how this theoretical model can be modified to incorporate the special facets of agricultural supply relationships, and to consider some previous studies relevant to the New Zealand dairy supply industry.

In order to achieve these aims the chapter is separated into three sections. The first section begins with the theory of the firm and builds a theoretical supply model. The theoretical model is then adapted to take account of situations where the application of inputs and the resulting output do not occur in the same period.

In the second section, the difficulties in supply analysis in general and in agricultural supply analysis in particular are discussed. The section also considers attempts to overcome some of the difficulties. The incorporation in supply analysis of price expectations and invest- ment in fixed and quasi-fixed factors of production are considered in some detail. In considering the investment in fixed and quasi-fixed factors of production, a model is developed that can take account of changes in investment in dairy livestock.

The final section is separated into two parts. The first part considers previous studies of the New Zealand dairy supply industry. The second part discusses studies made of how New Zealand farmers form their price expectations and models of price formation in New Zealand cattle auctions.

2.1 The Generalised Derivation of a Simple Multi-period Supply Function

The following sets out the derivation of a multi-period supply

function. Initially, the firm is assumed to produce two outputs and to use one input in the same period. The system is then generalised to a multi-period production system. The basis for the following is given in Henderson and Quant $\boxed{26}$.*

Consider the case of a firm producing two outputs (q_1 and q_2) by using one variable input (x) in the same period as output occurs. The relationship between input and outputs is termed the production function and can be written in its implicit form:

$$H(q_1, q_2, x) = 0 \qquad (2.1)$$

H is assumed to possess continuous first- and second-order partial derivatives which are different from zero for all its non-trivial solutions. Also, it is assumed that its partial derivatives with respect to outputs are positive and its partial derivative with respect to input is negative. It is further assumed that (2.1) can be written in the form:

$$x = h(q_1, q_2) \qquad (2.2)$$

where h denotes a production relationship.

The cost of production (C) is dependent on the price of the input (r) and the cost of fixed factors of production (b). C is expressed as:

$$C = r x + b,$$

which by substitution of x, from (2.2), becomes:

$$C = r h(q_1, q_2) + b \qquad (2.3)$$

The marginal costs of producing one more unit of q_1 (MC_1) and of q_2 (MC_2) each are derived from the first partial derivatives of (2.3) with respect to q_1 and q_2 respectively. They are:

$$\frac{\partial C}{\partial q_1} = r h_1'(q_1, q_2) = MC_1 \qquad (2.4)$$

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* Chapters 3, 4 and 8.

and
$$\frac{\partial C}{\partial q_2} = r\, h_2'(q_1,\, q_2) = MC_2 \qquad (2.5)$$

Assuming that the producer wishes to maximize profits, he forms the profit (π) function of the following form, using market prices for q_1 and q_2 (p_1 and p_2 respectively):

$$\pi = p_1\, q_1 + p_2\, q_2 - r\, h(q_1,\, q_2) - b \qquad (2.6)$$

The first order conditions for profit maximization are obtained by partial differentiation of (2.6) with respect to q_1 and q_2, and by equating these to zero. This yields:

$$\frac{\partial \pi}{\partial q_1} = p_1 - r\, h_1'(q_1,\, q_2) = 0$$

$$\frac{\partial \pi}{\partial q_2} = p_2 - r\, h_2'(q_1,\, q_2) = 0$$

By transferring p_1 and p_2 to the right hand sides:

$$p_1 = r\, h_1'(q_1,\, q_2) \qquad (2.7)$$

$$p_2 = r\, h_2'(q_1,\, q_2).$$

Equations (2.7) state that the firm will produce quantities of output that equates the MC of each output to its respective price. The second-order conditions can be shown to require that $\frac{\partial^2 C}{\partial q_i^2} > 0$ for maximum profit, which means that the MC's must be increasing.

As the price of q_1 alters, (2.7) will no longer hold at the previous solution levels for q_1 and q_2. The firm will adjust q_1, but this alters MC_2. Thus as each output price changes the firm must adjust both q_1 and q_2 for (2.7) to hold.

In the short run, the firm will attempt to produce quantities of output that just equate the respective MC's to prices. If the price of one output falls below the average variable cost (AVC), the firm will not produce any more of that product since sale of that product is no longer going towards meeting overheads. The relationships between output and costs are shown in Figure 2.1 where B is the minimum AVC

point and AB is the horizontal line from B to the vertical axis. Thus, the supply of q_1 from the individual firm, in response to changes in its own price, will follow the line OABC in Figure 2.1, given that all other prices remain constant.
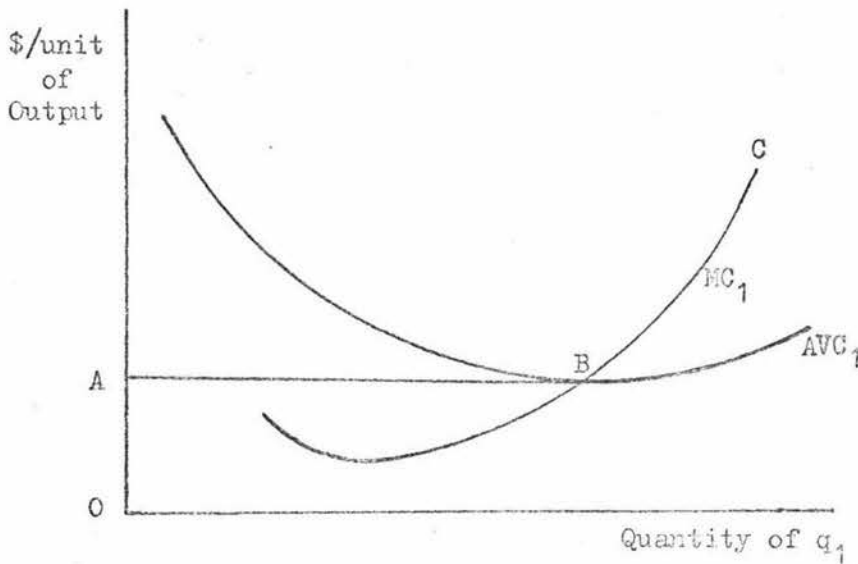
<u>Figure 2.1</u>: <u>The Hypothetical Average and Marginal Cost Curves of a Firm</u>

The quantity of q_1 and q_2 supplied by firm j (S_{1j} and S_{2j} respectively) can be obtained by solving (2.7) for q_1 and q_2. If the equations (2.7) are solved simultaneously, the quantity of each output supplied is dependent on the prices of outputs and the price of the input. Thus:

$$S_{1j} = s_{1j}(p_1, \ p_2, \ r)$$

$$S_{2j} = s_{2j}(p_1, \ p_2, \ r)$$

(2.8)

These supply functions are derived from the production function, the cost function and the profit maximization objective.

If the demand curve for the input is infinitely elastic, the industry supply function is obtained by the horizontal summation of the individual firm's supply functions. If m firms produce q_1 then the

industry supply of q_1 (S_1) would be determined by:

$$S_1 = \sum_{j=1}^{m} S_{1j} = \sum_{j=1}^{m} s_{1j}(p_1, p_2, r),$$

In general most firms apply inputs in a period before output occurs. For simplicity, consider a firm producing one output (q), one period after a single input (x) is applied. If the firm is concerned with an optimal production plan over n years, the implicit production function can be expressed as:

$$G(q_t, \ldots, q_n, x_{t-1}, \ldots, x_{n-1}) = 0 \qquad (2.9)$$

The assumptions concerning the production function for the single period input-output case remain.

If the individual firm wishes to maximize profits over time it will discount future income by a different factor for each year (e_t)* and will wish to maximize the present value of the profit from production subject to the technical constraints of the production function. The firm will form the profit function:

$$\pi' = \sum_{t=1}^{n} p_t q_t e_t - \sum_{t=1}^{n} r_{t-1} x_{t-1} e_{t-1}$$

$$+ \lambda G(q_t, \ldots, q_n, x_{t-1}, \ldots, x_{n-1}) \qquad (2.10)$$

where p = the price of q,

   r = the price x, and

   λ = a Lagrange multiplier.

The firm will then set the first-order partial derivatives equal to zero:

$$\frac{\partial \pi'}{\partial q_t} = p_t e_t + \lambda G'_{q_t}(q_t, \ldots, x_{n-1}) = 0,$$

$$\frac{\partial \pi'}{\partial x_{t-1}} = -r_{t-1} e_{t-1} + \lambda G'_{x_t}(q_t, \ldots, x_{n-1}) = 0,$$

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* For ease of notation the discount factor for year t is written as e_t where $e_t = \frac{1}{(1+i)^t}$ and i = the interest rate.

$$\frac{\partial \pi'}{\partial \lambda} = G(q_t, \ldots, x_{n-1}) = 0.$$

where (for example) $G'_{q_t}(q_t, \ldots, x_{n-1}) = \dfrac{\partial G(q_t, \ldots, x_{n-1})}{\partial q_t}$

It follows that the first-order conditions for maximizing π' are:

$$\frac{p_t e_t}{p_k e_k} = \frac{G'_{q_t}(q_t, \ldots, x_{n-1})}{G'_{q_k}(q_t, \ldots, x_{n-1})} , \tag{2.11}$$

$$-p_t e_t \frac{G'_{x_{k-1}}(q_t, \ldots, x_{n-1})}{G'_{q_t}(q_t, \ldots, x_{n-1})} = r_{k-1} e_{k-1} , \tag{2.12}$$

and $$\frac{r_{t-1} e_{t-1}}{r_{k-1} e_{k-1}} = \frac{G'_{x_{t-1}}(q_t, \ldots, x_{n-1})}{G'_{x_{k-1}}(q_t, \ldots, x_{n-1})} \tag{2.13}$$

for $t, k = 1, \ldots, n$.

Condition (2.11) requires that the ratio of product transformations between each period are equated to the ratio of the discounted output prices for those periods. Condition (2.12) states that the discounted value of the marginal product of x applied during the k-1 period with respect to output in each period, must be equated to the discounted price of x in the k-1 period. By condition (2.13) the ratio of the rates of technical substitution in the different time periods must be equated to the ratio of the discounted input price in each period the inputs were purchased.

As prices change the firm will need to adjust production through time in order that the conditions (2.11), (2.12) and (2.13) hold. Thus the individual firm's supply through time is a function of the output price for the current and each future period discounted for the period the output is to be sold, and a function of the input price for the current and each future period discounted for the period the input is purchased. If all the m firms in the industry use x to produce q, then the supply function for the industry (S_t) in period t is the horizontal

summation of all the n individual firms' supply functions (S_{jt}),
provided that the demand for the input is infinitely elastic. That is:

$$S_t = \sum_{j=1}^{m} S_{jt}(p_t e_t, \ldots, p_n e_n, r_{t-1} e_{t-1}, \ldots, r_{n-1} e_{n-1}). \qquad (2.14)$$

In practise, firms usually use several inputs to produce several
outputs. It can be shown that in this case the industry supply function
includes the prices of all the outputs and all the inputs for all the
periods outputs are sold and inputs are purchased, where the output
prices are discounted for the periods the production is sold and the
input prices are discounted for the periods the inputs are purchased.

2.2 Difficulties in Supply Analysis

The theory of supply just outlined, cannot be applied directly to
a given situation. In all cases, many of the assumptions made in the
theoretical model need to be relaxed. For example in practise the
assumption that the firm wishes to maximize profits very seldom holds.

The first part of this section considers the objectives of farmers.
Other problems associated with agricultural supply analysis are summarised
by Nerlove as: "problems connected with (1) the complex structure of
production, (2) technological change, (3) aggregation, (4) investment
in fixed or quasi-fixed factors, (5) uncertainty and expectations".
$\boxed{42}$, p.31 $\boxed{}$. These problem areas are expanded upon in this section and
means of overcoming parts of the associated problems are discussed.

2.2.1 Farmers' objectives

Several studies have considered the objectives of farmers and
attempted to test the relevance of profit maximization as a farmer goal.
Of the studies a large number have concentrated on the farm operator's
decisions concerning management under conditions of risk and uncertainty.*

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* In this context see Officer and Halter $\boxed{58}$ and McArthur and
Dillon $\boxed{35}$.

Patrick and Eisgruber $\sqrt{60}\_7$, in building a behavioural model of the farm firm, conclude that the farm family goals can be grouped into those connected with living standards, farm ownership, leisure-children and credit-using, risk-taking behaviour. They define these groups in the following manner. Living standards are connected with the desire for current income for current consumption. Farm ownership is related to the desire to own farm land and the desire to increase the farm's net worth.* Leisure-children is interpreted as being the desire for leisure and family time. Credit-using, risk-taking is the willingness to accept risk and reduce security to achieve other goals. They also conclude that the importance of the goals changes with the age of the farmer, net worth, size of the farm and size of the family $\sqrt{60}$, p.494$\_7$.

Lin et al. set out to test the hypothesis "that farmer's operational decisions are more consistent with utility maximization than profit maximization" $\sqrt{33}$, p.497$\_7$. They tested three alternative decision criteria: profit maximisation, Bernoullian utility maximisation and lexicographic maximisation of utility.** Each criteria was tested on 6 case study farms. None of the criteria gave good predictive results. Had the farmers wished to maximize profits they would have chosen plans furthest from those actually chosen. On the other hand, the maximization of a Bernoullian type utility gave results closest to those actually chosen by the farmers.

In conclusion Lin et al. suggest that better aggregate predictions would be obtained by aggregating farms on the basis of similarity of utility functions.

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* The authors do not define net worth but presumably they were meaning equity in the farm.

** The basis for the Bernoullian and Lexicographic utility functions was a mean-variance frontier for each possible crop the farmers could grow. The Bernoullian utility functions were estimated by each decision-maker 'playing' a series of 'games against nature'. The Lexicographic utility functions were determined by asking the decision-makers to rank their goals. Under a Lexicographic system the firm is assumed to maximize the least important goal, subject to 'satisfactory' levels of the dominant goals.

These studies support the contention that a farmer tends to
maximize utility.   That is, the contention that a farmer does not strive
to satisfy one goal but tries to achieve a balance between several goals.
The particular goals each farmer considers and the importance of each
goal depend on a wide range of factors.   Amongst the goals are the
goals of the farmer himself, of other family members, goals of peers
and goals possibly common to all farm families.   These goals may be in
conflict or have differing importance with different stages of life
$\underline{/}$23, pp.431-432$\underline{/}$.

2.2.2 Complexities of production

Agricultural production systems are complex.   A large number of
inputs influence production in the period they are applied and continue
to influence production in subsequent periods.   A further complexity
arises because factors interact to give combined effects on production.
Agricultural output itself is made up of a number of products: some of
which account for a large proportion of income on the individual farm
while others are more in the nature of by-products or products from
hobbies.   Each input has a different effect on each output.   Some
inputs have a specific use in the production of one particular output,
but the majority of inputs can be used in the production of several
outputs.

The theoretical supply model developed in the previous section
includes a supply function for each output of the firm.   It was shown
that the quantity of each output supplied is dependent on the prices of
all the outputs produced and the price of the variable input used by the
firm.*   Because of this large number of variables that need to be
considered in supply analysis, it is difficult to use regression
techniques to analyse supply relationships.

Nerlove states that "The complex structure of agricultural
production leads to serious problems in time-series analysis for two

* In fact a firm uses more than one variable input, especially in the
  longer run, and hence all the prices of these inputs need to be
  included.

reasons. Firstly, time-series are generally short relative to the number of variables which it would be desirable to include in statistical analysis in the light of the complexities of agricultural production; hence, only relatively few may be taken into account. Secondly, because many time-series, particularly prices, tend to move together over time, the separate effects of even those few variables included cannot be discerned" $\underline{/}$42, p.31$\underline{/}$.

In order to include the large number of variables in supply analysis, many researchers turn to analysing supply relationships using normative methods. One of the more commonly used methods are inter-temporal programming models. The problems of the complexity of the production system are, however, not overcome since prior estimation of the production and cost parameters is necessary.

Some researchers while recognising the problems of supply complexities project simple known trends. Cartwright $\underline{/}$9$\underline{/}$, for example, in projecting future exportable milk output from New Zealand, "simply projected according to plausible assumptions concerning rates of growth, without paying attention to causation" $\underline{/}$9, p.3$\underline{/}$.

In considering aggregate agricultural production, the number of variables that influence production is greater than the number that influence production on the individual farm. For example, where two farms include some inputs that are not common to both, the aggregate output of the two farms will be influenced by the full set of inputs. The full set of inputs will be greater than the average number of inputs of the two farms. In order to take account of the number of variables in either the aggregate or the individual situation, most studies combine several of the variables into one. The combining of the variables introduces a problem to do with aggregation. The subject of aggregation of production units is discussed in the next part of this section.

2.2.3 Aggregation

Two types of aggregation need to be considered in supply analysis. There is the aggregation of variables and the aggregation of production

units. Nerlove points out that "the necessity of confining attention
to a few relevant variables in time-series analysis is itself a form of
the aggregation problem" $\boxed{42, \text{ p.32}}$.

The form of aggregation discussed here is the combining of a number
of production units and the use of the aggregate to estimate the supply
relationships. The theory of supply begins with the theory of the firm
and sums the individual responses to obtain the aggregate response.
In practice the problem of handling a large number of individual
producers is often simplified by working with more aggregate production
units than the individual farms and farmers. In so doing, the estimated
output may not equal the actual event that occurs due to incorrect
aggregation of the production units.

The problem as Baker and Stanton see it is "to take all the individual
farms and farmers and consolidate them into an understandable whole which
will provide approximations to reality" $\boxed{3, \text{ p.711}}$. In order to
overcome part of the problem, they suggest that representative farms
should be drawn from homogeneous groups. The representative farms can
be used as a reasonable guide to how the group will respond. In
sorting farms into homogeneous groups, the aim is to reduce the
variation of the sample. A sufficient number of farms need to be
analysed to reduce the errors to a 'tolerable level' and a criteria is
required to sort the farms into homogeneous groups. Baker and Stanton
suggest that the groups should be sorted according to some important
production trait.

Frick and Andrews $\boxed{19}$ in studying the problem of aggregation bias
obtained linear programming 'supply functions' for each of 51 farms.
These 51 supply functions were summed to provide a measure of the
industry's supply functions that were assumed to be free from aggregation
bias. Four methods of selecting representative farms were employed and
the estimated supply functions, appropriately weighted and summed, were
obtained. The differences between the estimated supply responses
using the four methods and that obtained from the sum of the 51 farms
gave a measure of the level of aggregation bias. The four methods of
selection used were: (1) the average farm, developed by taking the
mean of the resources of the 51 farms;   (2) the present size of the
farms;   (3) the most limiting resource;   and (4) the potential size of
the farms.

The selection method that closely reproduced the aggregate results was the grouping according to the most limiting resource. When using this method, however, as Frick and Andrews point out, problems of farm size and level of technology are ignored and other problems arise when making projections and when handling more than one product.

The selection of representative farms depends on the particular situation. El-Adeemy and MacArthur [15] considered procedures for the selection of representative farms and suggest that the modal farm in each homogeneous group may be a better indicator of the group's response to changing stimuli than the average farm.

2.2.4 Technological change

Technology as defined by Henderson and Quant [26, p.54] is all the technical information available to the producer concering the various combinations of the inputs in the production of outputs and includes all physical possibilities. A change in the amount of technical information available, when applied to the production system, causes a technological change. A technological advance allows more output from the same quantity of inputs, or the same output from less inputs. In other words, the advance causes an increase in the efficiency of production.

The difficulty for the supply analyst is to measure the amount of technical information and so quantify changes in the amount being used. As Heady states, "These variables are difficult to measure and express in direct quantitative and logical relation to supply. New resources arise as specific capital items and innovations, and they do not have price observations tying them with time-series observations of other variables" [24, p.23].

Technology changes with time but not necessarily at a constant rate of change. Cochrane [12], in considering technological advances in United States agriculture argues that over long periods, changes in production efficiency have occurred in spurts rather than gradually. During some periods, especially some short periods, the level of technology has remained constant.

In quantifying supply relationships, researchers often choose a short period or assume that no structural changes due to changes in technology have occurred over the period in question. The assumption of no technological change does not hold for longer time periods. Nerlove $\int 42\int$, in considering time-series analyses, states that "over longer periods of time, to which time-series refer, it is clear that this assumption (of no change) is a poor one. In time-series analyses for individual commodities, a simple trend has generally been used to take account of the effects of changing technology" $\int 42$, p.32$\int$.

A time trend, however, is only of use if changes in production efficiency have been gradual. Even then Learn and Cochrane, when discussing regression estimation of supply relationships, point out that a linear time trend "can result in biased coefficients for other independent variables which exhibit a secular trend" $\int 32$, p.70$\int$.

There are other methods of taking account of changes in technology. Two of the more common involve the use of dummy variables and surrogates for technological change. Dummy variables can take account of sudden changes in technology by adjusting the constant term in a regression equation for different time periods. A surrogate for technological change is a variable that is considered to change with changes in technology. Cromarty $\int 14\int$, when building a supply model of dairy production in the USA, used the number of dairy herd improvement associations as a surrogate for the level of technology.

2.2.5 Uncertainty of prices and production responses

The farm operator, making plans for the future, has two broad areas of uncertainty. He is uncertain as to what input and output prices to use in planning and he is uncertain about the likely output he will achieve with a given bundle of resources. Prices are uncertain because markets are uncertain. The uncertainty of production responses arises through the uncertainty of future weather, disease and pest incidences and through the variability of the various production units (in this case the variability between livestock).

The method a farm operator might be expected to use in projecting prices are discussed here. The variability of supply response is discussed later.

2.2.5.1   Price expectation formulation

The theoretical model outlined earlier assumes that the firm knows
the future prices it will receive for output and pay for inputs.   In a
dynamic situation the farmer does not know the prices he will receive and
pay in the future.   Even so the farmer must plan for the future and
in order to make a plan the farmer must use the prices he thinks he
will receive and pay.   These future prices the farmer uses are 'price
expectations' and will be likely to differ from those that eventuate.
As the farmer's price expectations change, his plan for the future will
change and current actions will alter.   Carvalho $\sqrt{10}$, in discussing
the formation of price expectations, states "that individuals react to
current values of variables and to their expected future values is
well established in economic theory.   How expectations are generated
is still a matter of debate.   It is unlikely that there is a unique
explanatory mechanism" $\sqrt{10, p.85}$.

Hicks $\sqrt{27}$, in considering the relationship between the
producer's expectations of the future price and the current price of a
commodity, defines the 'elasticity of expectations' where "the elasticity
of a particular person's expectations of the price of commodity X (is)
the ratio of the proportional rise in expected future prices of X to the
proportional rise in its current price" $\sqrt{27, p.205}$.   If the
elasticity is zero, the current price does not influence the future
expected price.   If the elasticity is unity, a change in the current
price will cause expectations of the future price to change in the
same proportion.

The cobweb model was one of the first theories to explicitly
develop a model of price expectation formation.

The Cobweb Model

The cobweb model is adapted from static economic theory where
supply is predetermined.   The model, outlined by Ezekeil $\sqrt{17}$*,
assumes that (1) production in any one period is determined by

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* The model is also summarised by Waugh $\sqrt{64}$.

producers' response to price under conditions of perfect competition;
(2) the production period is such that at least one full period is
required before output can be changed; and (3) demand does not shift
$\sqrt{\ }$17, p.274$_7$.

The producer is assumed to expect the price in the next period (P^*_{t+1})
to be the current price (P_t). That is:

$$P^*_{t+1} = P_t .$$

In order to adapt the theory to be more compatible with observed
price and quantity fluctuations, several qualifications to the theory
are required $\sqrt{\ }$17, 13$_7$. The main interest in the theory, however,
has centered on the conditions required for the system to be stable.

In considering the cobweb theory and the conditions under which it
can be applied, Buchanan $\sqrt{\ }$7$_7$ concludes that the theory is only valid
under very special circumstances. He also concludes that in general,
the theory implies constant losses by producers and that people do not
learn from experience.

Extrapolative Expectations

Metzler $\sqrt{\ }$37$_7$ put forward the extrapolative expectation theory as
an alternative to the cobweb theory. The basis for extrapolative
expectations is the assumption that producers project some proportion of
the trend through the most recent known prices. That is:

$$P^*_{t+1} = P_t + g (P_t - P_{t-1}) .$$

where g is Metzler's coefficient of expectation, which adjusts the
most recent price for the trend in the last two prices. Metzler makes
the point "that expectations of future sales may depend not only upon the
past level of sales, but also upon the direction of change of such sales"
$\sqrt{\ }$37, p.119$_7$. In a footnote, Metzler compares his coefficient with
Hicks' elasticity of expectation and concludes that $(1+g)$ equals Hicks'
elasticity $\sqrt{\ }$37, pp.119-120$_7$.*

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* Metzler defines Hicks' elasticity of expectation as:
$$= \frac{P^*_t - P_{t-2}}{P_{t-2}} \div \frac{P_{t-1} - P_{t-2}}{P_{t-2}}$$

In analysing the extrapolative expectations model, Arrow and Nerlove [2, p.298] point out that the extrapolative properties of the model hold only if $g > 0$. If $g = 0$, the model reduces to the cobweb model. In the case where $g < 0$, the expected price equals the weighted moving average of the past two years' prices.

Some support for extrapolative expectations comes from Williams [65] who in considering the price expectation and production plans of milk producers in Indiana (USA), found that producers project recent prices into the future with only minor modification. Williams concludes that the elasticity of price expectations amongst the surveyed farmers may be nearly unity.

Adaptive Expectations

Cagan [8] put forward the model of adaptive expectations, based on the elasticity of expectation developed by Hicks. In this model producers are assumed to adjust their expectations in the light of the most recent information. The form of the expectation is:

$$P_t^* - P_{t-1}^* = \gamma (P_{t-1} - P_{t-1}^*) \text{ , for } |\gamma| < 1.$$

γ is the coefficient of expectation which "determines the rapidity with which expected rates of change in prices adjusts to actual rates" [8, p.37]. If the prices are in logarithms γ becomes Hicks' elasticity of expectation.* If $\gamma = 1$, the model becomes the cobweb model.

By assuming that $0 < \gamma < 1$, it can be shown that:

$$P_t^* = (1 - \beta) \sum_{i=0}^{\infty} \beta^i P_{t-1-i}$$

where $\beta = 1 - \gamma$**. This expression states that the expected price is the weighted average of all previous actual prices, where the weights decline geometrically with the lag.

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* Arrow and Nerlove assume time to be discontinuous and, on the basis that individuals think in terms of a 'normal' price, let the expected price be the 'normal' price expected at the beginning of the period [2, p.299].

** See Carvalho [10, p.92].

A similar type of expectation formation model sometimes used is a weighted average of only a few past prices. Patrick and Eisburger $\underline{/}60\underline{/}$, for example, in studying the supply responses of farmers, use a weighted moving average of the previous three years prices of the form:

$$P_t^* = 0.7\ P_{t-1} + 0.2\ P_{t-2} + 0.1\ P_{t-3}.$$

Rational Expectations

Muth $\underline{/}40\underline{/}$ proposed a model of price expectation formation which he termed 'rational' and hypothesised that expectations are essentially the same as the predictions of the relevant economic theory. The rational expectations model is based on three hypotheses concerning an individual's behaviour: "(1) Information is scarce, and the economic system generally does not waste it. (2) The way expectations are formed depends specifically on the structure of the relevant system describing the economy. (3) A 'public prediction', ..., will have no substantial effect on the operation of the economic system (unless it is based on inside information)" $\underline{/}40,\ p.316\underline{/}$.

In this model, the producer is assumed to have some idea of market price making forces and uses these in forming his expectations.

Some support for Muth's rational expectations can be found in research concerning farmer's price expectation formation. Heady and Kalder found that "for their 1948 and 1949 forecasts the majority was not using simple mechanical models such as the projection of the current price or recent price trend into the next year but was attempting to analyse tnd predict the more complex price-making forces. A rather common procedure appeared to start the process of devising expected prices from current prices. The current price was then adjusted for the expected effects of important supply-and-demand forces. Where farmers possessed little information about these forces, there was a tendency to project either the current price or the recent price trend" $\underline{/}25,\ p.35\underline{/}$.

Muth $\underline{/}40\underline{/}$ suggests that the aggregate expected price of the firms for period t+1 (in period t) must be equal to the expected value

of the market equilibrium price for period t+1 predicted by the market forces in period t. That is to say, the expected price is an unbiased estimate of the market price and the expected price is endogenous to the system.

Consider an example given by Muth $\underline{/}$ 33, pp. 317-320 $\underline{/}$:

The particular market is assumed to consist of a demand function:

$$C_t = -\beta p_t;$$

a supply function,

$$S_t = \gamma p_t^* + u_t;$$

a market equilibrium condition,

$$S_t = C_t;$$

and a price expectation function,

$$p_t^* = E_{t-1}(p_t).$$

where C_t = the amount consumed in period t,

S_t = the number of inputs produced in the period lasting as long as the production lag,

p_t = the market price in period t,

p_t^* = the expected price for period t,

β, and γ are constants and

u_t is an error term.

Muth assumed that all variables were expressed as deviations from equilibrium values.

If the errors between periods are serially correlated, Muth shows that the solution to the expected price is:

$$p_t^* = \frac{\beta}{\gamma} \sum_{j=1}^{\infty} (\frac{\gamma}{\beta+\gamma})^j p_{t-j},$$

which states that the expected price is a geometrically weighted moving average of past prices where the weights depend on the supply and demand coefficients $\underline{/}$ 40, p.320 $\underline{/}$.

Thus Muth's rational expectation model requires the specification of demand, supply and expectation functions and a market equilibrium condition. The expectation function is an integral part of the market forces and cannot be determined separately from these market forces.

2.2.5.2 The uncertainty of production response

Production plans for the future contain elements of uncertainty due to the uncertainty of the response from a given bundle of resources. An important cause of the uncertainty of the production response in agriculture is the variability of what is loosely termed 'weather'.

'Weather' is the conglomeration of many factors. In supply analyses, the aspect of weather that influences production and the period over which that aspect of weather has its influence are difficult to ascertain. It is even more difficult to quantify the aspect of weather and include it in a supply model.*

Mules $/$39$/$, in studying the supply response of dairy farmers in Australia, summarises the various methods of excluding or including weather as an explanatory variable in supply analysis in the following manner:

(a) Select or modify a dependent variable so that it is free of the influences of weather.

(b) Assume that weather is random and therefore can be relegated to the error term.

(c) Use rainfall, sunshine, temperature evaporation etc. measurements to quantify the effects.

(d) Use a broad surrogate of the weather influence where the surrogate can be a factor greatly affected by weather formed into an index of the changes of the variable from its trend through time $/$39, p. 197$/$.

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* For example see Maunder $/$34$/$ who attempts to predict monthly dairy production from water deficiency data.

The method to use in either incorporating weather into, or
excluding it from, supply analysis will depend on the product being
studied, the time period being studied and the measurability of the
particular aspect of weather influencing production.   For example, in
an aggregate supply model, rainfall measurements will not be a reliable
guide to the influence of weather if the weather differs between regions
within the aggregate.

2.2.6   Investment in fixed and quasi-fixed factors of production

The following section is separated into three parts.   The first
part considers some aspects of investment theory that are relevant to
supply analysis.   The second part discusses some attempts to incorporate
investment theory into supply analysis and the third part considers the
investment behaviour of a dairy farmer.

Some Aspects of Investment Theory

Current and future levels of farm output (i.e. supply) will be a
function of past and current management decisions with respect to the
allocation of resources.   Examples of such decisions may be the
expansion or renewal of some factors of production such as durable
inputs or the expansion or retraction of livestock numbers.   Services
from durable inputs will be derived over a period of time.   Similarly,
decisions made with respect to the retention of livestock will,
depending on the type of stock involved, affect output for some time
after the decisions have been made.

All such decisions are called investments since the farmer is
spending money (or sacrificing consumption) in the current period in
the expectation of earning a stream, or flow, of annual income over some
future period.   The theory of investment deals with the rationale
underlying such investment decisions.   The theory also considers
criteria to guide the individual in selecting among a number of
alternative income streams.

In the theory of investment an individual is assumed to have a
time preference for consumption which is based on his intertemporal
utility function.   For the individual, a sum of money in the current

period is worth more than the same sum of money in the next or some
later period. The extra amount that would need to be paid to the
individual in the next period so that he is indifferent between an
amount in the current period and the same amount in the next period,
depends on the individual's rate of time preference.

Fisher $\sqrt{18\_7}$ considered that the individual would wish to
distribute consumption through time in order to maximize utility.
He differentiated between investment opportunities (productive invest-
ments) such as the purchase of livestock, and exchange operations such
as borrowing and lending money. Fisher showed that the investment
opportunities cannot be evaluated separately from the consumption
alternatives.

In the Fisherian view of investment, the individual must choose
between the productive investments available to him in order to attain
his optimal intertemporal consumption pattern. Criteria such as net
present value (NPV) and internal rate of return (IRR) have been devised
to assist in the selection between productive investments. The NPV of
a productive investment is the sum of the discounted stream of income
from the investment. That is:

$$NPV = \sum_{j=1}^{n} \frac{b_j - c_j}{(1 + i)^j} \; ;$$

where b_j = the gross income received at the end of the years
  $j = 1, \ldots, n$,

  c_j = the costs incurred at the end of the years
   $j = 1, \ldots, n$,

  i = the market interest rate, and

  n = the last year the investment provided an income
   or incurred a cost.

The IRR is the discount rate that equates the present value of the
gross income stream and the present value of the costs stream. That
is where:

$$\sum_{j=1}^{n} \frac{b_j - c_j}{(1 + r)^j} = 0 \; ;$$

where r = the internal rate of return.

In the theory of investment, the individual selects an optimum productive investment from those available with the aid of an investment criteria. He will then adjust the income stream between periods by either borrowing or lending. The type and extent of the exchange operation will be determined by the individual's intertemporal utility function.

Consider the case where the individual has four investment opportunities (E1, ..., E4) that are independent of each other and that involve two periods. The four investment opportunities are shown in Figure 2.2 where for example, E2 yields an income of oa in the first year and ob in the second year. It is assumed that a perfect capital market exists where the borrowing and lending rates of interest are the same and equal i. In Figure 2.2 the constant market rate of interest is denoted by the parallel lines whose slope equals $-(1+i)$.
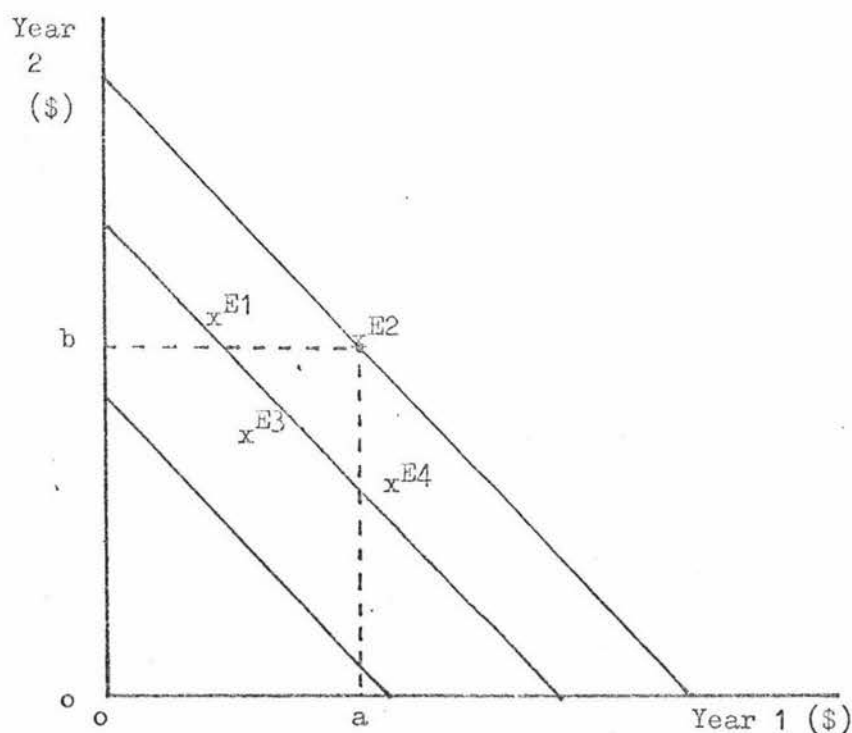
Figure 2.2: Two Period Investments

In this case, E2 is the investment opportunity with highest NPV (when using i as the discount rate).

By superimposing a set of indifference curves (derived from the individual's intertemporal utility function) on Figure 2.2, the exchange operation that the individual should perform can be derived. This is given in Figure 2.3. In this example the individual should borrow an amount ac in year one and should repay an amount bd in year two in order to attain the highest level of utility. Therefore he would be able to attain point P in Figure 2.3 and would consume oc in year one and od in year two.
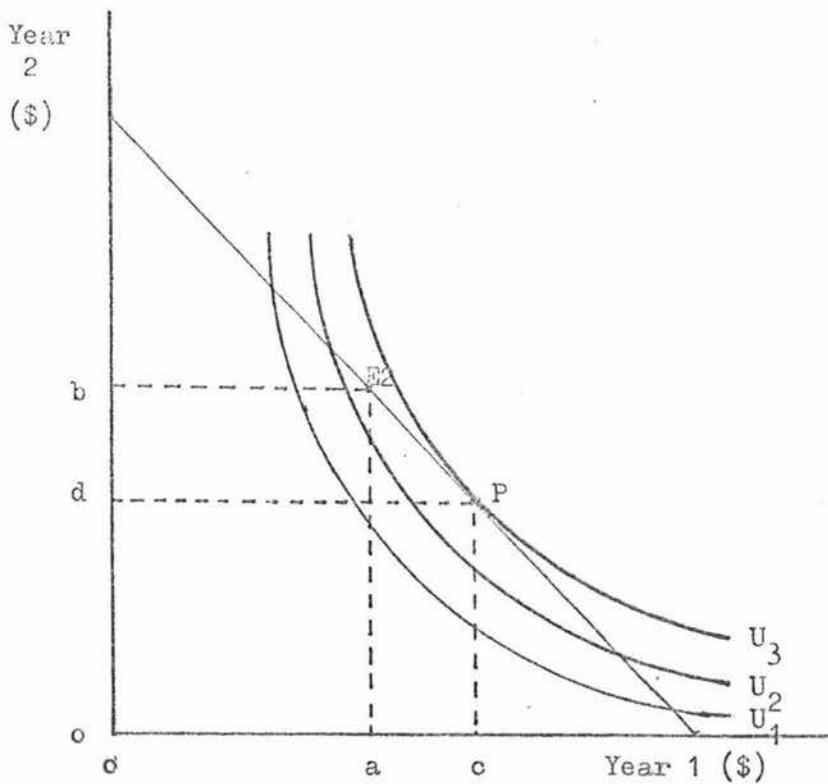
Figure 2.3:   A Two Period Solution

Thus, Fisher showed that the investment process is made up of two steps: a productive investment step and an exchange operation step. But because little is known of the indifference curves of the individual (or of the firm or society) the type and extent of the exchange operation must be left to the individual to determine. All that can be considered for the individual is which investment opportunity to select.

In extending Fisher's analysis, Hirshleifer [29] considered the conditions under which the NPV and the IRR rules could be used to guide an individual in selecting between productive investments. He showed, using iso-quant analysis methods, that once the assumption of a perfect capital market is dropped (i.e. that the borrowing and lending interest rates are not equal) the NPV and IRR criteria will not in a all cases indicate the same solution as the iso-quant analysis. Further, Hirshleifer found that where the marginal cost of borrowing increased as the quantity borrowed increased, NPV and IRR can lead to wrong investment decisions.

After investigating other conditions under which the two rules would correctly indicate the same solution as his iso-quant analysis, Hirshleifer concluded that "the present value rule is correct in a wide variety of cases (but not universally)" [29, p.351] but it fails to give the same solution as his iso-quant analysis when investment opportunities are non-independent and where changes in the ranking of investments occur by using different interest rates. Hirshleifer also concluded that "the main burden of the analysis justifies the contentions of those who reject the internal rate of return as an investment criteria" [29, p.329].

Investment and Supply Analysis

Many attempts have been made to include in supply analysis the affects of changes in capital items on production [22, 41]. But the quantities of the capital items themselves change in response to economic stimuli, especially in livestock production where the capital items include the livestock which are used to provide an income stream over future time periods. As Hildreth and Jarret [28, p.21] point out at any given time an animal is a final good, a good in process

or an item of capital.   The decision to sell an animal is a decision
to invest in less of that class of livestock.

Three recent studies $\underline{/}$ 10, 30, 66 $\underline{/}$ have analysed cattle production
relationships by considering cattle as investment goods.   Carvalho
$\underline{/}$ 10 $\underline{/}$ studied the investment behaviour of a cattleman in the United
States and claimed that "the results yield a good approximation to the
cattleman's behaviour" $\underline{/}$ 10, p.139 $\underline{/}$.   In a similar manner to Carvalho,
Yver $\underline{/}$ 66 $\underline{/}$ and Jarvis $\underline{/}$ 30 $\underline{/}$ built investment models of an Argentina
cattleman's behaviour.   Jarvis pointed out that "the central theme is
simple.   Cattle are considered to be capital goods which are held by
producers as long as their capital value in production exceeds their
slaughter value.   In essence producers become portfolio managers seeking
the optimal combination of different categories of animals to complement
their non-cattle assets, given existing conditions and future
expectations" $\underline{/}$ 30, p.489 $\underline{/}$.   In both studies, the results were considered
by the authors to describe the behaviour of Argentina cattlemen better
than previous attempts.   Jarvis concluded that the results "should
abolish doubts as to whether Argentina producers respond to prices"
$\underline{/}$ 30, p.517 $\underline{/}$.

These studies provide an introduction to the concept of cattle as
investment items.   In dairy production, cattle can be considered as
capital items, and decisions to change the size and composition of a dairy
herd can be considered as investment decisions.   The following
discussion considers changes in the size and composition of a dairy herd
from an investment point of view.   This discussion draws upon the
studies of Carvalho $\underline{/}$ 10 $\underline{/}$, Yver $\underline{/}$ 66 $\underline{/}$ and Jarvis $\underline{/}$ 30 $\underline{/}$.

The Investment Behaviour of a Dairy Farmer

A dairy farmer is in business to produce milk and other products
such as calves and cull cows, in order to earn an income.   His desire
for consumption between periods will induce him to adjust production
which he will do by the decisions he makes.   The management decisions
facing the dairy farmer concern the size and composition of the cattle
herd he should retain to maximize his future income stream, and the
level of inputs.   The former is mostly an investment decision and
the latter is a current production decision.   For example, if the

dairy farmer desires a higher current income he may retain less calves and/or retire more cows.

The dairy farmer's decisions will depend on his expectation of future prices. If he expects the future price for milkfat to increase he may retain more female calves and retire less cows and increase inputs to achieve a higher production from the increased stock numbers. Thus the dairy farmer is investing for future output and hence income. One of the inputs the dairy farmer may increase is the area of land available to the milking herd. This can be achieved by bringing more land into productive use by development, or by expanding the size of the farm. Both these are investment decisions though some of the increases in production will be realised in the current year.

While recognising the importance of effective farm size decisions, this study does not explicitly treat investment decisions concerning the effective farm size. The analysis considers only the short run where the dairy farmer takes the effective farm size as fixed.

The dairy farmer can be considered as an investor-producer who uses many resources to earn an income. Some of these resources (his milking herd and replacements) will produce income over time and thus can be considered as capital assets which the dairy farmer will build up or deplete depending on his expectation of the future income stream. His investment decisions concern the number of female calves to rear as herd replacements (sacrifice from current income), the number of male calves to rear and the number of milking cows to retire. It is possible for a dairy farmer to sell some of the heifers not in the milking herd,* but these are small in number.

The decisions on the number of cattle to retain reduces to deciding the optimum age to sell an animal. Female animals have the potential to produce milkfat and calves each period, as well as providing meat at slaughter. On the other hand, males (other than a small proportion)

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* In this study, the dairy farmer is assumed to milk all available heifers in preference to milking a cow due for retirement.

produce only meat at slaughter. Therefore, a female calf at birth is more valuable than a male calf, since the stream of income from the female is expected to be higher than that for a male.

The dairy farmer is interested in making investment decisions so as to maximize utility. In the majority of cases, the first step should be to maximize the net present value (NPV) of the expected income stream from each animal.

The NPV of a female animal at time t (V_{ft}) is the sum of the discounted value of future milkfat production, plus the discounted value of the calves born plus the discounted future value of the cow in period k when sold, minus the discounted costs of the input stream. That is:

$$V_{ft} = \sum_{j=t}^{k} \frac{PM_j\ MP_j}{(1+i)^j} + \sum_{j=t}^{k} \frac{VC_j}{(1+i)^j} + \frac{PC_k\ W_{fk}^{\cdot}}{(1+i)^k} - \sum_{j=t}^{k} \frac{C_{fj}\ PI_j}{(1+i)^j} \quad (2.15)$$

where t = the current period,

k = the period in which the animal is to be sold,

f indicates a female animal,

i = the discount rate (assumed for simplicity to be constant),

PM_j = the expected milkfat price for period j,

MP_j = the expected milkfat production for period j,

VC_j = the expected value of the calf crop for period j and is dependent on the calving rate, the probability of the calf being male or female, and the expected future value of male and female calves,

PC_k = the expected price per unit of weight of the cow for period k,

W_{fk} = the expected weight of the cow for period k,

C_{fj} = the expected inputs per female animal for period j, and

PI_j = the expected price of inputs for period j.

The decision facing the dairy farmer is to choose the k that will maximize V_{ft}. This is the same as saying that the dairy farmer chooses k so as to maximize the capital value of each animal. Since some females are sold as calves and others are retained for milk production, function (2.15) could be considered as being bimodal [30, p.498] For some females, however, their discounted future income stream must be less

than their value as vealers.   Dairy farmers retain female calves from
higher producing earlier calving cows and thus function (2.15) will be
maximized for some females at five days old and others after serving a
period in the milking herd.   It can be shown that for all ages below k,
the capital value must exceed the market value, but at k will equal the
market value $\boxed{66, p.18\_\!\!\_}$.   At this point the dairy farmer is indifferent
between retaining the animal and selling it.   Thus, for a transaction
to occur at less than the slaughter age of the cow, the market price
must exceed its future productive and slaughter value.

A cow should be retired from the herd and slaughtered when the NPV
of the future expected income stream (capital value) equals or is less
than the current slaughter value of the animal.   If the value of a
cow, when slaughtered, increases (ceteris paribus) the dairy farmer
should retire more older cows since PC_k will exceed the V_{ft}s of some
of the older cows.   If the increase is expected to persist then the
dairy farmer should also retain more female calves since their V_{ft}s
will increase above their value as vealers.   An expected increase in
the future milkfat price (ceteris paribus) will increase the V_{ft} of
females of all ages, hence less cows should be retired (or their retire-
ment age should increase) and more female calves should be retained as
herd replacements.   Similarly, an expected drop in the input costs
associated with holding females will raise the V_{ft} of all females with
the same effect as an expected increase in the milkfat price.   An
increase in the discount rate will decrease the V_{ft} of all animals and
hence less female calves should be reared and more cows retired.

A further avenue of investment readily available to the dairy
farmer is to retain some male calves.   The options here are to sell the
male calves at five days of age, as weaners of 3 to 4 months of age, in
the early spring as yearlings or for slaughter in the following autumn.*
The NPV of a male animal at time t (V_{mt}) is given by:

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* See Barry $\boxed{4, p.13\_\!\!\_}$.   Given that about half of the New Zealand
  dairy farmers use artificial insemination methods $\boxed{44\_\!\!\_}$, the
  keeping of bulls for breeding purposes is not considered here.

$$V_{mt} = \frac{PB_k W_{mk}}{(1 + i)^k} - \sum_{j=t}^{k} \frac{C_{mj} PI_j}{(1 + i)^j} \qquad (2.16)$$

where the variables are as defined for function (2.15),

    m indicates a male animal, and

    PB_k = the expected price per unit of weight of a male
animal for period k.

The decision the dairy farmer makes is to choose k such that V_{mt} is maximized. As before, at this k the market value of the animal equals its future V_{mt}.

Traditionally in New Zealand, the number of male calves reared by dairy farmers has been small and the number wintered on dairy farms even less $\underline{/}$4, p.12$\underline{/}$. For ages less than the slaughter age (of 18 to 20 months), sales should occur only where the market price per unit of weight exceeds the slaughter price $\underline{/}$66, p.17$\underline{/}$. Some evidence for this can be seen in sales of dairy/beef* animals in New Zealand where, as the slaughter age approaches, the price per unit of weight at which the animal changes ownership, declines $\underline{/}$21, p.25$\underline{/}$.

It can be shown that the optimum slaughter age of a male animal is where the rate of weight gain equals the rate of interest plus the daily feed costs per dollars worth of the animal $\underline{/}$66, p.18$\underline{/}$. That is, where marginal return equals marginal costs.

Thus, as the price of beef from male dairy animals increases, or is expected to increase (ceteris paribus), more male calves should be reared since for some of them their discounted future value will exceed their current value as vealers. A drop in the price of inputs or in the discount rate should have a similar effect.

The dairy farmer thus holds, or potentially can hold, a mixed portfolio of animals of different sex and ages. In the short run, if he aims to maximize his future net revenue stream, he should "try to

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* The definition of dairy/beef used here is given in Barry $\underline{/}$4$\underline{/}$, p.12.

equalise the rates of return to investments in (his) mixed portfolio" /66, p.18_7. As prices and discount rates change, or are expected to change, the dairy farmer will adjust his portfolio. He should adjust his portfolio by investing in that class of animal that has the highest capital value.

In the short run the area of land available to the dairy farmer is fixed, and thus he will want to disinvest in that class that has the least capital value or else increase inputs other than land to maintain the extra stock. For example, if the price of milkfat is expected to increase the dairy farmer should invest in more cows and female calves. But the increase in the number of cows in the herd will differ from the increase in the number of calves since the NPV of the older cows not retired will differ from the NPV of the extra calves reared. At the same time the dairy farmer may increase the level of inputs to maintain the higher stocking rate. On the other hand, if the price of meat from dairy animals is expected to increase the dairy farmer should invest in (more) male calves and less cows but will be forced to invest in less female calves. The extent of any shift between the various categories of livestock and between livestock and material inputs will depend also on the respective marginal costs of using each type of input to increase output by say one dollar.

Thus in order to study the supply responses of the dairy industry to changing prices, it is necessary to determine the effects of changing prices on the stock of capital. It is by changing the stock of capital that the dairy farmer adjusts future income. The actual level of future income will depend also on the level of material inputs. Thus the decisions concerning the level of material inputs are an integral part of the analysis.

The variables that are involved in the decisions concerning stock numbers and inputs are specified in functions (2.15) and (2.16). These variables are current and expected output and input prices, the current and expected quantities of inputs and outputs and the discount rate(s). In Chapter Four, a model of a dairy farm is built based on function (2.15).

This study is based on a representative farm and thus, the NPV of each animal on the farm has to be summed to obtain the capitalised

expected income stream. The order of summation of the capitalised income stream does not alter the result, so that expected income in each period can be obtained and this income stream capitalised. This approach is followed in Chapter Four.

Before building an empirical model to attempt to explain the supply responses of dairy farmers and to test it against actual data, the region from which the data is derived needs to be analysed. This is the subject of the following chapter.

2.3 Relevant Previous Studies

The following discussion is aimed primarily at outlining previous studies of the supply of dairy products in New Zealand. The section is separated into two parts. The first part considers studies of New Zealand dairy supply, and the second section outlines New Zealand farmer price expectation and price formation models.

2.3.1 New Zealand dairy supply studies

Three quantitative studies concerning the supply of dairy products in New Zealand have been published $/\overline{}4, 5, 36\underline{}7$. In the earliest of these Bergstrom $/\overline{}5\underline{}7$ used data for the period from 1922 to 1938 to estimate supply equations for dairy products and dairy cow numbers (as well as meat, wool and livestock). He assumed the entrepreneur planned to maximize his expected stream of cash surpluses subject to a production function limitation and that the elasticity of the entrepreneur's price expectations* was unity. The price expectation assumption, which meant that expected future prices moved in exactly the same proportion as the current price, allowed Bergstrom to use current prices in the year of production. By including the number of livestock in the supply equations, Bergstrom was able to build a simultaneous model of dairy,

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* The definition of the elasticity of the entrepreneur's price expectations is given in Hicks $/\overline{}27$, p.205$\underline{}7$ and is discussed earlier in this chapter.

sheep and beef production and included changes in cattle and sheep numbers.

For the dairy equations the price elasticity of supply turned out to be negative. In discussing these results, Bergstrom argued that: "A likely explanation of the negative supply elasticities is that, because of income effects, profit maximization is not consistent with the maximization of farmer's utility" [5, p.267]. There are, however, other explanations that could be made.

Bergstrom ignored the influences of technology changes and weather on production. Over the period from 1922 to 1938, both these factors are likely to have affected production. Mutton and lamb prices have tended to move together* and thus, due to problems of multi-collinearity, the reliability of the estimated coefficients would be reduced. Another point is that Bergstrom's dairy cow equation contained prices lagged by only one year. In aggregate, dairy cow numbers can only increase in New Zealand by rearing more female calves. The time lag between an increase in the number of female calves and an increase in the number of cows in milk is two years. As, over the period of the study, the number of cows in milk was increasing, a two year time lag in prices would have been more appropriate. A further criticism, is the omission of the prices of the capital items. In other words, the model excluded allowance for the investment decisions in more or less dairy cows.

A study by Barry [4], using data from 1957 to 1970, considered the growth potential of the New Zealand beef and dairy herds. He used single equation lagged adjustment models to explain the number of cows in milk (DCM). The only estimated equation published for DCM was:

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* The correlation between the logarithm to base 10 of the two series is 0.9804.

$$DCM_t = -26,288.92 + 3.46\ PMF^*_{t-2} + 0.57\ DCM^{***}_{t-1} + 13.66\ T^{**}$$
$$(1.62) \qquad\qquad (4.12) \qquad\qquad (2.39)$$

where PMF_{t-2} = an index of the price of milkfat at factory door
two periods previously,

DCM_{t-1} = the number of dairy cows in milk one period
previously,

T = a time trend, 1957, ..., 1970,

R^2 = .997.

The values in parentheses are student t values of the coefficients
directly above them. The short run elasticity of cow numbers with
respect to the price of milkfat = .18 and the long run elasticity = .42.

As an aggregate model of the changes in the number of dairy cows in
New Zealand, Barry's model appears reasonable. The time trend and part
of the previous year's cattle numbers take account of shifts in technology.
A criticism is that changes in technology over the period have not been
gradual and thus a linear time trend would not account for spurts in
the use of new technology. As in Bergstrom's model, the price of cull
cows has not been included.

The only study of relevance to the Taranaki/Western Uplands region
(the region of interest in this study), is that by Meister [36],
He used a regional linear programming approach to estimate interregional
changes in the supply of milkfat and dairy/beef for the North Island of
New Zealand. Meister considered the regional effects of milkfat price
changes and market quota restrictions assuming two objective functions:
(a) an objective of minimizing the cost to the nation of producing a
certain quantity of milkfat; and (b) a farmer goal of maximizing profit.

Using data on the average farm for each region in each herd size
category for 1966/67, Meister found that the Taranaki/Western Uplands

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* Coefficient differs significantly from zero at the 10% confidence level.
** " " " " " " " 5% " "
*** " " " " " " " 1% " "

region was a high cost dairying region and that the region would not
respond to changes in the price of milkfat over the range of prices
considered.   Meister did not discuss these particular findings, since
he was interested in other matters, but the higher cost of dairy farming
in Taranaki would be due to the higher fertilizer required for intensive
livestock farming in the region $\boxed{50}$.   The result of no response to
the price of milkfat indicates that the price elasticity of supply of
milkfat is zero.   This zero elasticity implies that the marginal costs
of dairy farming in the region falls sharply as production decreases.
However, given that the region is a high cost one and the high cost is
due to the extra fertilizer (a variable input) required, the average
variable costs in the region are likely to be higher than in other
regions.   The implications of this high variable cost for the average
farm is that as prices for output fall, some farms in the region would
be expected to go out of production before farms in other regions in New
Zealand.

Meister's findings for New Zealand were that as the price of milkfat
fell the farm supply response would be inelastic at medium prices, but as
the price fell further, production would fall severely as farmers turned
to beef production.

2.3.2 New Zealand dairy farmers' price expectations

In New Zealand, dairy farmers are insulated from the short term
market forces and need not consider these forces in forming their short
term price expectations.   The payout for milk related products is set in
advance for each season and is based on prices paid to dairy factories
which have been set by an independent authority.   The independent
authority (the Dairy Products Pricing Authority) takes into account
market forces in New Zealand's export markets and stabilisation
regulations.   Cull cow prices are set each week by the meat exporting
companies and surplus calf prices are set (in Taranaki) by the Pig
Marketing Association.*

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* See Chapter Three.

No published information is available on New Zealand (and in particular Taranaki) dairy farmers' price expectations. The only information concerns price expectations and price formation models of New Zealand sheep and beef farmers.

Davey,* in a study of sheep farmers' price expectation formation used an adaptive price expectation model. The results indicated that the farmers adjusted their new expectations considerably for the error in their previous expectations.

Two other studies are of interest. Walker [63] and Gillingham [20] studied price formation in New Zealand store cattle auctions. They found a high level of explanation of the auction prices was due to the price meat exporting companies were prepared to pay for the meat of that class of animal at the time of the auction. The implications are that beef farmers projected the current meat schedule price into the period when the animal was expected to be slaughtered.

For the purposes of this study, the conclusion is made, therefore, that sheep and beef farmers use simple models to project future prices, and in the absence of information to the contrary, dairy farmers are assumed to do likewise.

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* Reported in Scott [62].

CHAPTER THREE

RELEVANT TRENDS IN THE REGION UNDER STUDY

The aim of this chapter is to describe the data used in this study and to discuss some of the changes that have occurred in the data. The data is drawn from a sample of dairy farmers whose production systems vary between each other and from year to year. This chapter considers the data from the sample as if the average of the data was a farm in its own right. The farming system is simplified by considering the important variables and lumping the other components of the system into a simple relatively unimportant category. The assumption is made that the important variables are common to all the dairy farms in the sample and have much the same effect on each farm.

This study considers an important dairy farming region in New Zealand which is selected for the homogeneity of the sample from which the data is drawn and for the stability of the farming systems within the region. The Taranaki/Western Uplands region from 1963/64 to 1973/74, has remained an important dairying region with no great trend away from dairy production. The homogeneity of the sample is increased by studying only the factory milk supply dairy farms which make up over 95 percent of the farms in the sample $\boxed{43}$.* However, the homogeneity of the sample is reduced by the inclusion of the Western Uplands region.

In the first section of this chapter the price setting mechanism, the release of price information and the sources of the price information used in the study are discussed. The second section considers the

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* The 1963/64 data is not separated into cream and milk supply farms and so the data for that year includes the cream suppliers.

the sources from which the physical and financial data used is
derived. The third section outlines the major changes that have
occurred in the average farm of the Taranaki/Western Uplands region.
The fourth section analyses these changes in a simple manner and the
final section summarises the chapter and includes the conclusions of
the simple analysis.

3.1 Price Setting and the Release of Price Information
to Suppliers in the Taranaki Region

In this section the payout system for milk supplied to factories
in Taranaki is discussed. The price for surplus calves and cull cows
are then discussed. Finally a brief review of movements in output and
input prices is given.

3.1.1 Milkfat prices

Milk supplied to a factory, is processed into two groups of
products; those processed from the milkfat portion (e.g., butter)
and those processed from the solid-not-fat (SNF) portion of the milk
(e.g., skim milk powder). The price the supplier receives is derived
from the factory income minus manufacturing costs of the different
products. The payout is then usually based on the quantity of milk-
fat received by the factory.

In July of each year the Dairy Products Pricing Authority (DPPA)
announces an advance price it will pay to dairy companies for milk
products during the season. The system of setting the advance each
year has changed over the last two seasons. In the following, the
system prior to the changes is discussed and then the changes
themselves are outlined.

Prior to 1975 the advance for the milkfat related products had to
be set so that the advance did not rise more than 5 percent nor fall by
more than 5 percent on the previous season's average total payout
$\underline{/}$ 55, p.1713 $\underline{/}$. The advance included the full expected realisations
for milkfat related products plus 75 percent of what the DPPA

estimated for the SNF related products realisations $\underline{/}$55, p.1725$\underline{/}$.

Each dairy company then converted the advance set by the DPPA to an advance to suppliers. The conversion to an advance to suppliers was made by subtracting the estimated costs of manufacture from each product price and then adjusting the balance for the proportion of milkfat in the final product.

In the Taranaki region the advance to suppliers was usually announced in late July. This advance was usually well below the total advance estimated from the advance to the companies by the DPPA (see Table 3.1). As the season progressed, upward adjustments were made to the advance. These adjustments were retrospective for the season and thus amounted to a considerable sum of net income. The adjustments usually occurred in: December, to cover Christmas and fertilizer expenditure; in February, to cover taxation and rates; and in May and June to provide an income over the winter months.

In late July, the final payout for the previous season was set and announced. The final payout usually included any differences in estimated and actual manufacturing costs, company profits, the value of SNF stocks held by the New Zealand Dairy Board (NZDB), any trading surplus made by the NZDB in SNF products, plus dispersements of any trading profits made by the NZDB for milkfat products. The final payout was usually spread over July, August and September to maintain suppliers incomes during the period of little or no production. The final payout was once again a few cents a kilogram on total milkfat supplied to the factory.

The timing of changes in payout for a major Taranaki dairy company are shown in Table 3.1.

From the foregoing it is obvious that suppliers, at the beginning of the season, could budget on receiving substantially more during the season than the initial advance, and in fact in most years they would have been told the estimated total advance for the season.

Following meetings between the NZDB and the dairy companies in October each year, the individual companies obtained market information and prospects. From this information the companies got some idea of

Table 3.1:   Changes in the Payout for Milkfat

Date	1973/74	1974/75	1975/76
	(cents/kg for 'Finest' grade milkfat)		
20 July	72	90	90
20 October	6	–	–
	78		
20 December	5	6	6
	83	96	96
20 February	5	6	8
	88	102	104
20 April	2	–	–
	90		
20 May	6	3	2
	96	105	106
20 June	6	6	6
TOTAL ADVANCE	102	111	112
20 July	12	10	12
	114	121	124
20 August	12	9	10
	126	130	134
20 September	10.4	5.25	10
TOTAL FINEST GRADE	136.4	135.25	144

SOURCE: Taranaki Co-op Dairy Company.

whether an extra end of season payout from the NZDB for milkfat related products was likely. Very little of this information was passed on to suppliers but at about Christmas time of each year the suppliers obtained an indication of whether they could expect a final payout for the season.

In mid 1975 the system of payout by the NZDB was altered to include the setting of the prices of the SNF related products under stabilisation regulations. The advance payout for SNF and milkfat related products must now be set not more than 5 percent below nor 10 percent above the previous season's average total payout $/\overline{}56, p.916\overline{}/$. This change means that the advance prices for both SNF and milkfat related products are subject to the same price stabilisation regulations.

These changes to the payout system reduces the variability of the total milkfat payout. Thus, suppliers will know at the beginning of the season, the total advance for the season. Any final payout will come from either the company's profits or from any trading profits dispersed by the NZDB. These changes may mean that the suppliers will receive a higher advance and lower final payout, in which case, the suppliers will be able to make a closer estimate of the total payout for each season.

3.1.2 Surplus calf prices

Calves, surplus to dairy farmers' requirements for rearing, need to be held on farms for at least four days before they can be sold for slaughter. The calves sold for slaughter, are sold through a local 'pool',* which, under government regulation, controls the collection and transport of these calves $/\overline{}57, p.815\overline{}/$. In Taranaki, there are approximately 20 bobby calf pools operating.** Some of these pools have the calves slaughtered by the local freezing works and then sell the meat, vells, skin and offal to the Pig Marketing Association (PMA).***

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* A committee of local farmers which is termed a 'Bobby Calf Pool'.

** Personal comment.

*** A producer co-operative operating throughout New Zealand.

Other pools sell the calves directly to the local freezing companies, but the vells are sold by the NZDB $\underline{/}$ 55, p.1724; 57, p.817 $\underline{/}$.

The price paid to farmers for surplus calves is derived from the different components of the calves. The price for vells is set by the Minister of Agriculture each March after consultation with the NZDB. The prices for the other components are set by the PMA and the freezing companies. All buyers make an initial payment to the pools at the end of August and September for the calves collected up to those dates. This initial payment tends to be approximately half the total payment for the calves. Some of the pools retain this payment until the final payment is made.

A final payment is made by the PMA in late February and by the freezing companies in March. All payments tend to be related to the payments made by the PMA.

3.1.3 Cull cow prices

Old cows, retired from dairy herds, are usually sold to local freezing companies for slaughter. The main period over which the cows are retired (culled) occurs from April to June as the cows finish producing milk $\underline{/}$ 52 $\underline{/}$. The companies set the prices they are prepared to pay farmers for animals for slaughter. These prices differ for different weight ranges of the carcases of the cows and are set each week in advance.

3.1.4 Sources of price series and movements in prices

A series of prices paid to suppliers for milkfat supplied to dairy factories is obtained from the annual reports of six representative dairy companies in Taranaki.* The series is the weighted mean of the individual company's payouts for whole milk from each company's shareholder suppliers. The weights are the proportions of the total milkfat handled

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* The companies are listed in notes to Table A.2 , Appendix A.

by each company.   The mean payouts are taken to represent the prices
paid to dairy farmers for milkfat in the Taranaki/Western Uplands region
and are given in Table 3.2.   An Index of the total milkfat payout is
graphed in Figure 3.1.

Table 3.2:   Representative Prices Paid to Suppliers for Milkfat from
   1963/64 to 1975/76 in Taranaki (c/kg)

	Advance	Final	Total
1963/64	72.186	13.629	85.815
1964/65	78.421	17.430	95.851
1965/66	79.268	19.235	98.503
1966/67	73.902	17.241	91.146
1967/68	64.169	12.322	76.491
1968/69	58.774	13.970	72.744
1969/70	62.256	11.547	73.803
1970/71	66.898	18.951	85.849
1971/72	84.977	22.968	107.945
1972/73	91.497	19.879	111.376
1973/74	101.562	28.240	129.802
1974/75	111.156	20.803	131.959
1975/76	113.317	33.664	146.981

SOURCE: Table A.2, Appendix A.

The NZDB publishes a NZ average price paid per head for calves
purchased by the bobby calf pools [44].   This average price is taken
to represent the prices paid to dairy farmers in Taranaki for their
surplus calves.   Annual changes in this series are graphed in
Figure 3.1.

Representative cull cow prices have been taken from the North
Island Meat Exporters' Schedule for boner cows in the last week of May.
The schedule is published by the NZ Meat Producers' Board [45].   An
average carcase weight for this grade is approximately 160·kilograms [47].
An index of the annual movements in prices per head for dairy cows is
graphed in Figure 3.1.
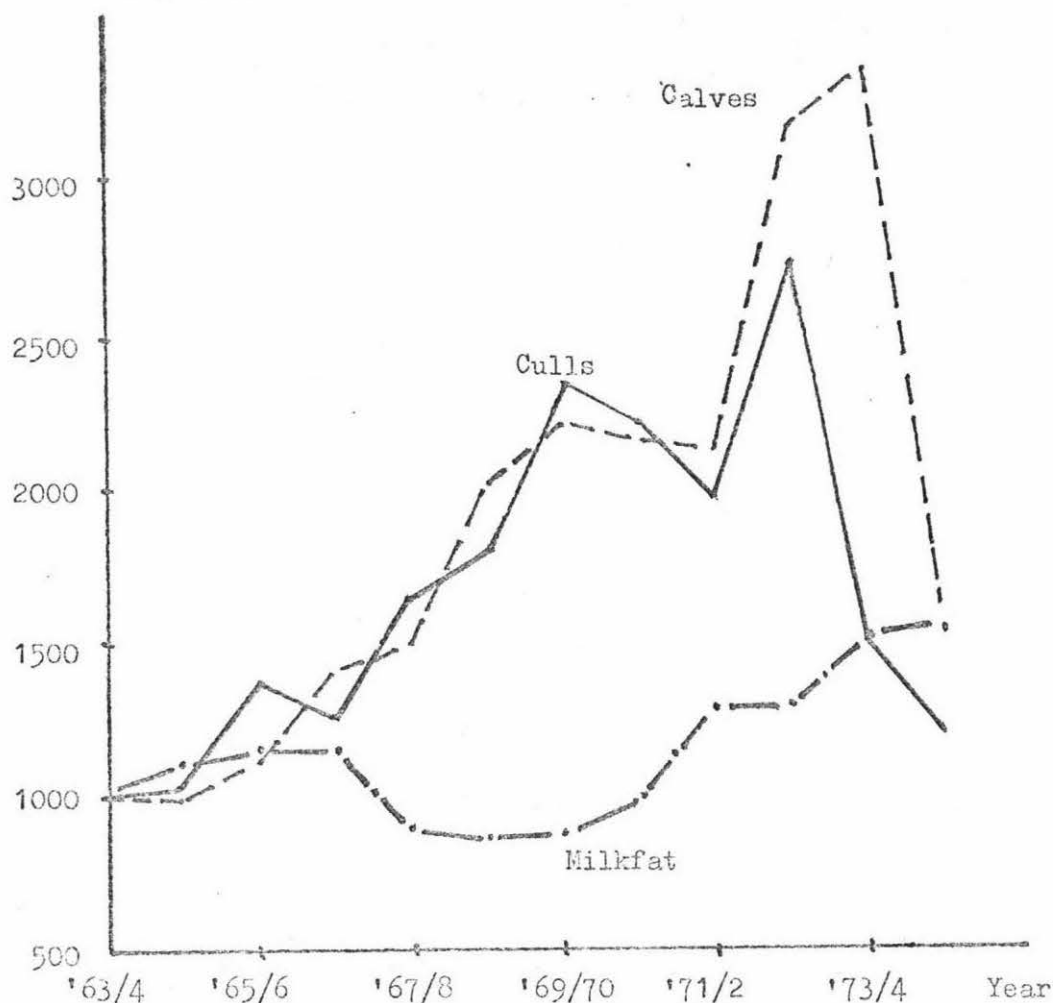
Index of prices

SOURCE: Appendix A, Table A.2

Figure 3.1:   Index of Price Movements

From 1963/64 to 1973/74 the total payout for milkfat increased by
an average of 3.8 percent per year.   Over the same period the prices
for surplus calves increased from $4.35 to $15.08;   an increase of 12.0
percent per year.   In May 1964, farmers received approximately $35.20
per head for cull cows.   By 1973 this had increased to $97.01 per head,
but fell to $52.80 in 1974.   The increase from 1964 to 1974 is an
average of 3.8 percent per year.   As can also be noted in Figure 3.1,
milkfat prices increased more than cull cow prices, but less than surplus
calf prices from 1963/64 to 1973/74.   It can also be noted that cull
cow and surplus calf prices are less stable than milkfat prices.

The NZDB publishes indices of the prices paid and received by New Zealand dairy farmers $\sqrt{44}$. The index of prices paid by dairy farmers may not represent the true movements in the prices paid for dairy farm inputs.* However, in this study the index is assumed to be representative of the price changes. The annual changes in these indices are graphed in Figure 3.2. From 1963/64 to 1973/74 the index of prices received by dairy farmers increased by 5.9 percent per year on average. Over the same period the index of prices paid by dairy farmers increased by an average of 4.9 percent per year. As can be noted in Figure 3.3, output prices have increased faster than input prices in the two periods from 1963/64 to 1966/67 and from 1968/69 to 1972/73.

3.2 The Farm Production Division's Survey of Factory Supply Dairy Farms

This study uses data from many sources. The physical and financial data on the average of the factory milk supply dairy farms in Taranaki/Western Uplands is obtained mostly from the NZ Dairy Board, Farm Production Division's (FPD's) survey of factory supply dairy farms. The information from this survey is published as an annual publication $\sqrt{43}$ and as part of the FPD's annual report $\sqrt{44}$. Information on total stock numbers on a regional basis is obtained from the Government Statistician's census of livestock numbers in New Zealand $\sqrt{51}$.

The FPD's survey gathers information on individual farms from the farmers' financial accounts. The balance dates of the accounts vary from March to June of each year and no attempt is made by the FPD to adjust them to a common balance date. The survey uses a sample of dairy farmers drawn from those willing to participate each year.

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* The index of prices paid by dairy farmers is compiled by weighting the individual items in farm expenditure by the proportion of total expenditure on each item. Thus, the index includes the effects of changes in the proportions spent on each item. The proportion spent on a particular item may increase because of an increased use of that particular item without the increased use of all other items. Therefore, the index will only reflect the true changes in prices if the quantities of each input remain in the same proportion to each other as prices change.

Index of prices
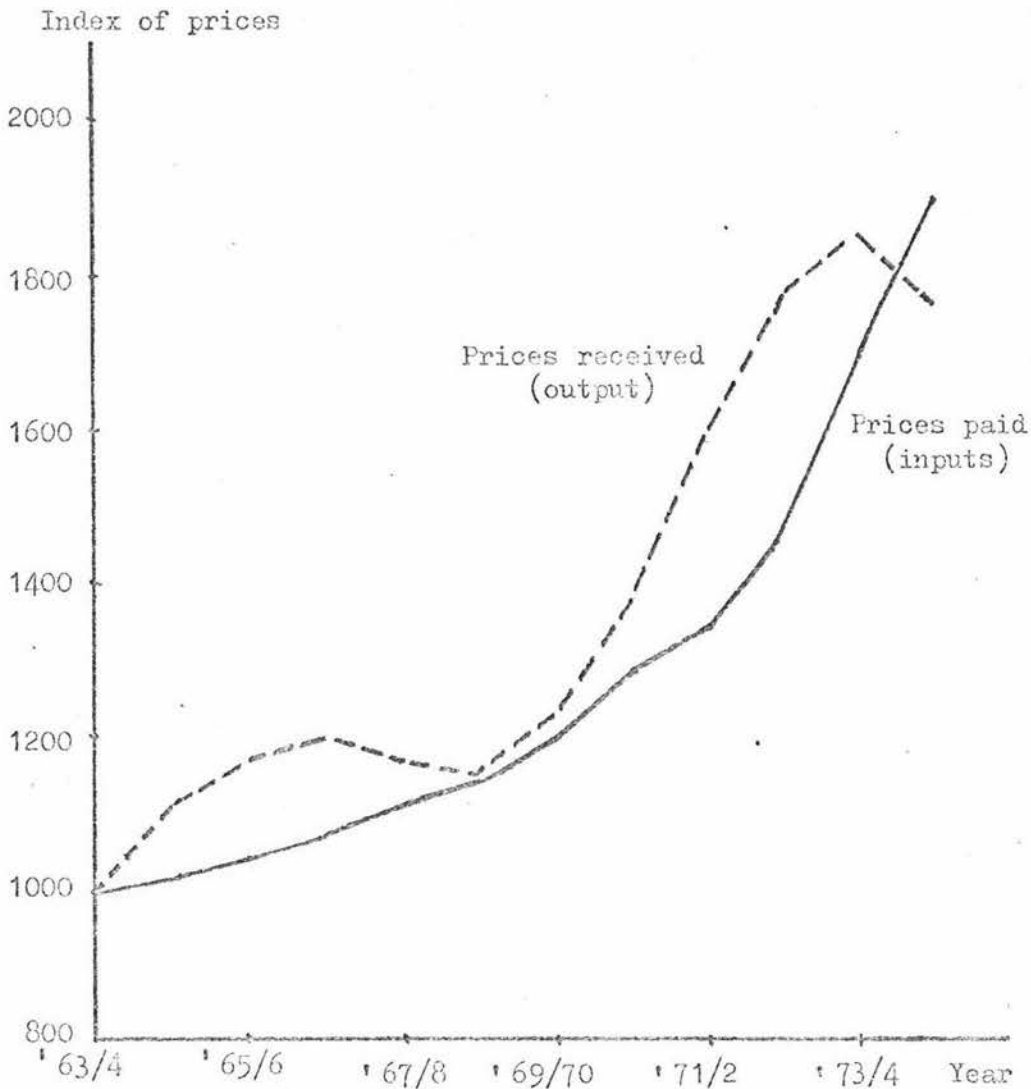
SOURCE: Appendix A, Table A.2

Figure 3.2: Indices of Prices Paid and Received by Dairy Farmers in
New Zealand

A random sample of new factory suppliers is added to the sample each
year so that a sample of 10 percent of eligible farmers is obtained.
A farmer is included in the sample if he is willing to lend the FPD a
copy of his accounts, the accounts are in a suitable form, the farmer
receives more than 75 percent of his income from dairy farming (including
pigs), he milks at least 30 cows, does not supply town milk, does not
employ a share milker and his ownership system is 'uncomplicated'.
All accounts are then adjusted to an 'owner-operator' basis by excluding
farms operated by share milkers and adjusting inter-family leases and
salaries to sons.

The level of bias in the survey cannot be accurately assessed.
The New Zealand Government Statistician publishes the number of dairy
cattle in New Zealand based on a livestock census on a regional basis
$\lfloor$51$\rfloor$. The number of dairy cattle includes town milk and factory
supply herds of 10 or more cows. The average number of cows per herd
from the census is approximately 9 percent less than the average herd
size in Taranaki from the FPD's survey.

Meister $\lfloor$36$\rfloor$ considered the discrepencies in the North Island of
New Zealand total number of farms, number of cows and milkfat produced
estimated from the FPD's survey as compared with other sources of the
data $\lfloor$36, pp.73-80$\rfloor$. Meister concluded that:

> "Because of the many calculations, and the many
> assumptions made, it is not possible to do a test
> to reconcile (the) differences between calculated
> and real totals. Errors will have come in all
> along the way. Not withstanding that, it is
> believed that (the) discrepencies are within
> acceptable limits, and do account for output and
> cows on the farms of other butterfat suppliers
> not taken into account in this study." $\lfloor$36, p.70$\rfloor$

The FPD defines Total Farm Income (TFI) as the income derived from
the sale of milkfat, the gross profit from the cattle account, the gross
profit from the calf account, the gross profit from the pig account, the
gross profit from other livestock, and other farm income. The other
livestock account includes the profits from sheep, horses, dogs and
poultry. Other farm income is the income from cash cropping, contracting,
wool and skins, value of produce consumed and other items.*

Farm expenditure is listed by the FPD under several headings.*
The general items of expenditure such as freight, fertilizer, and seed,
labour and development expenditure are included under Farm Cash Expenses
(FCE). Depreciation, deferred expenditure and income equalisation
account adjustments (prior to 1966/67, taxation concessions on fertilizer

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* For a definition of these items see $\lfloor$43$\rfloor$, vol.X, p.39.

and investment, were included in place of income equalisation adjust-
ments) are added to cash expenditure to give Total Farm Expenditure (TFE).

3.3 The Taranaki/Western Uplands Region

The structure of the dairy industry in Taranaki/Western Uplands is
discussed in this section.   The Taranaki region includes the counties
of Clifton, Taranaki, Inglewood, Egmont, Eltham, Waimate West, Hawera
and Patea.   Western Uplands is comprised of Waitomo, Taumarunui and
Waimarino Counties.   The two regions are of similar size but topography,
soil types and therefore farming systems differ between them.   In the
Taranaki region in 1971/72, 84 percent of the farms and 49 percent of
the livestock units* were of the dairying type.   In Western Uplands
in 1972/73 these proportions were 32 percent and 2 percent respectively.
However, the Western Uplands contained less than 4 percent of the dairy
cattle in the combined region $\boxed{51}$

In the combined region dairy farming is heavily concentrated on the
foothills of Mount Egmont $\boxed{43}$.   In the Waimate West county, for
example, in 1965/66, 94 percent of the rural land area was devoted to
dairy farming and 87 percent of the farms were full time dairy farms.
A further 2 percent of the farms were mixed sheep and dairy $\boxed{49}$.
Part of the reason for this concentration is that the soils in the
foothills of the mountain are generally free draining, friable and stand
up to intensive dairy farming in a wet climate $\boxed{50, p.53}$.

From 1963/64 to 1973/74 the number of cows in milk in the region
increased at an average rate of 1.3 percent per year.   Over the same
period the number of suppliers declined by an average of 1.9 percent per
year and the number of dairy co-operative companies declined by an
average of 6.8 percent per year.   The annual changes are shown in
Figure 3.3.

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* Livestock units are the weighted sum of different classes of livestock
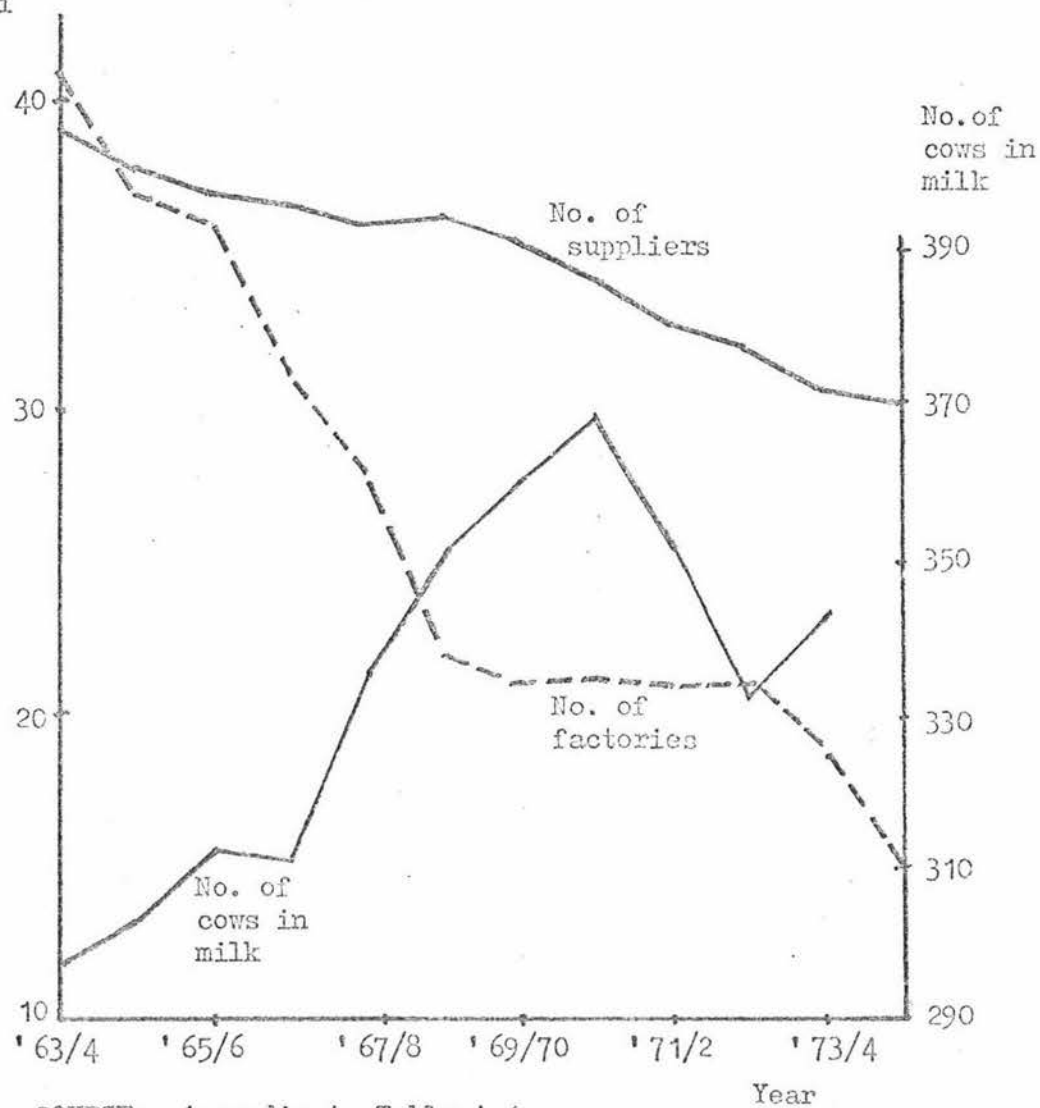where the weights are given in $\boxed{48}$, p.10.

Figure 3.3:   Changes in the Taranaki Region

3.3.1 The changes in the average of the Taranaki/Western Uplands factory milk supply dairy farms

In this section the changes that have occurred on the average of the Taranaki/Western Uplands factory milk supply dairy farm are discussed. The discussion considers the average as if it were a farm. The period under consideration is from 1963/64 to 1973/74.

Total Farm Income (TFI) on the average farm increased from $9342 in 1963/64 to $24,566 in 1973/74. The annual changes in TFI and the components of TFI are graphed in Figure 3.4. As can be noted, the major influences on TFI were changes in milkfat income. The proportional contributions to TFI from the various sources in 1963/64 and 1973/74 are set out in Table 3.3. The annual changes in the proportional contributions to TFI are graphed in Figure 3.5.

As can be noted in Figure 3.5 and Table 3.3, the importance of income from milkfat declined over the period of study, but continued to be the most important source of income. The percentage of income from milkfat, cattle and surplus calves increased from 92 percent in 1963/64 to 95 percent in 1973/74. This increase was due mainly to the increased importance of cattle income. The income from pigs and other sources declined.

A breakdown of other farm income for 1973/74 is given in Table 3.4. This breakdown indicates that cash cropping as a source of income in 1973/74 was not very important.

For this study an attempt is made to separate out into an item called 'cow input costs' the expenditure that influences per cow performance, from the expenditure that is influenced by changes in cow numbers.* Further, the amount of expenditure on development, insofar as it can be identified, is subtracted from Farm Cash Expenditure (FCE) to give an estimate of current cash expenditure.** The annual changes

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* See the notes to Table A.4, Appendix A, for a listing of the items included in cow input costs.

** See Table A.4, Appendix A.
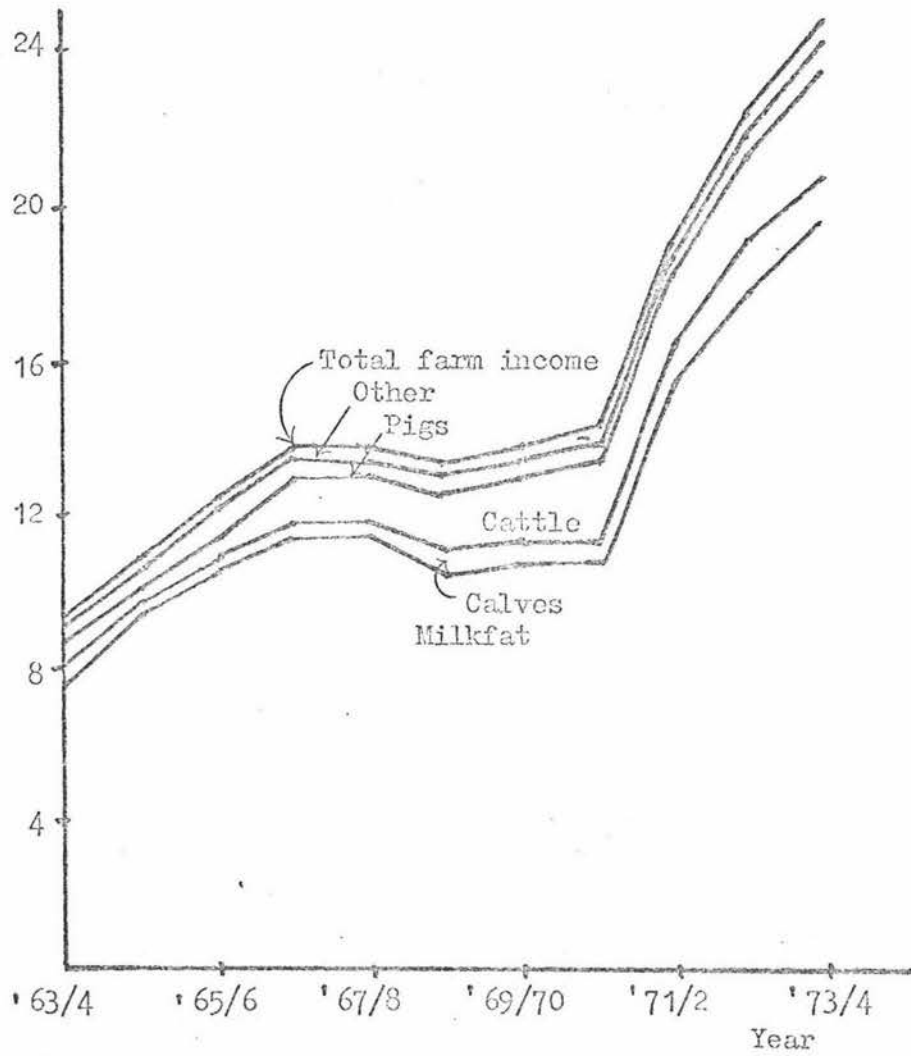
Figure 3.4: Sources of Total Farm Income (TFI)

Table 3.3:   Percentages of Total Farm Income From Various Sources

	1963/64	1973/74
	(%)	
Milkfat	82.1	80.0
Calves	2.5	3.7
Cattle	7.3	11.7
Pigs	5.8	2.6
Other stock	-0.4	0.1
Other farm income	2.7	1.8
Total Farm Income	100.0	100.0

SOURCE: New Zealand Dairy Board /43_7.

Table 3.4:   Breakdown of Other Farm Income as a Percentage of
Total Farm Income in 1973/74

	(%)
Cash crops	0.15
Contracting	0.53
Wool & skins	
Value of produce consumed	1.16
Other	
	1.84

SOURCE: New Zealand Dairy Board /43_7
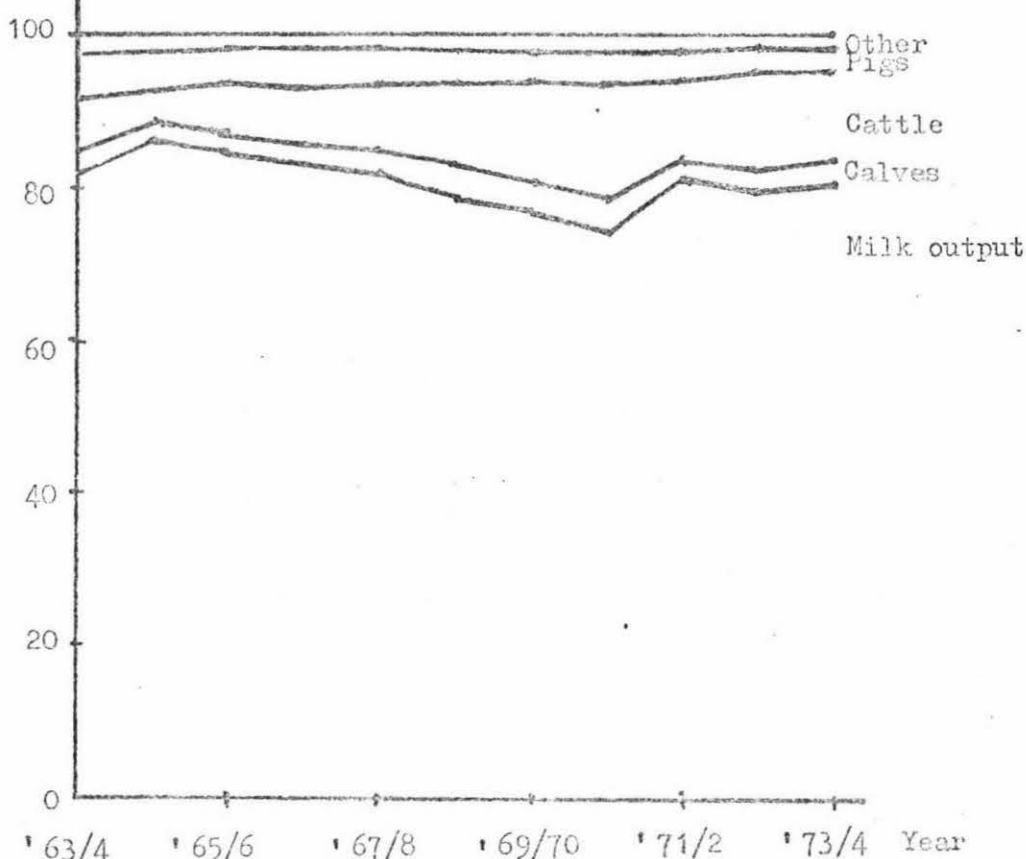
Figure 3.5: Percentage of Total Farm Income From Various Sources

in these items are graphed in Figure 3.6.   Over the period of the study,
TFE increased from $5810 (when it was 62 percent of TFI) to $14,432 (when
it was 59 percent of TFI).   The annual average increase in TFE was
8.6 percent.

In 1963/64, the average factory supply dairy farm in Taranaki/
Western Uplands contained 85 cows in milk. By 1973/74 the average
factory milk supply dairy farm had increased to 121 cows, which is an
average increase of 3.3 percent per year.   Over the same period the
effective farm area had increased from 44 to 61 hectares, an average
increase of 3.0 percent per year.   Cow inputs (real cow input costs)
increased at an average of 3.3 percent per year.   Thus, stocking rate
increased only slightly and cow inputs per cow remained constant.

Farm Expenditure

($'000)
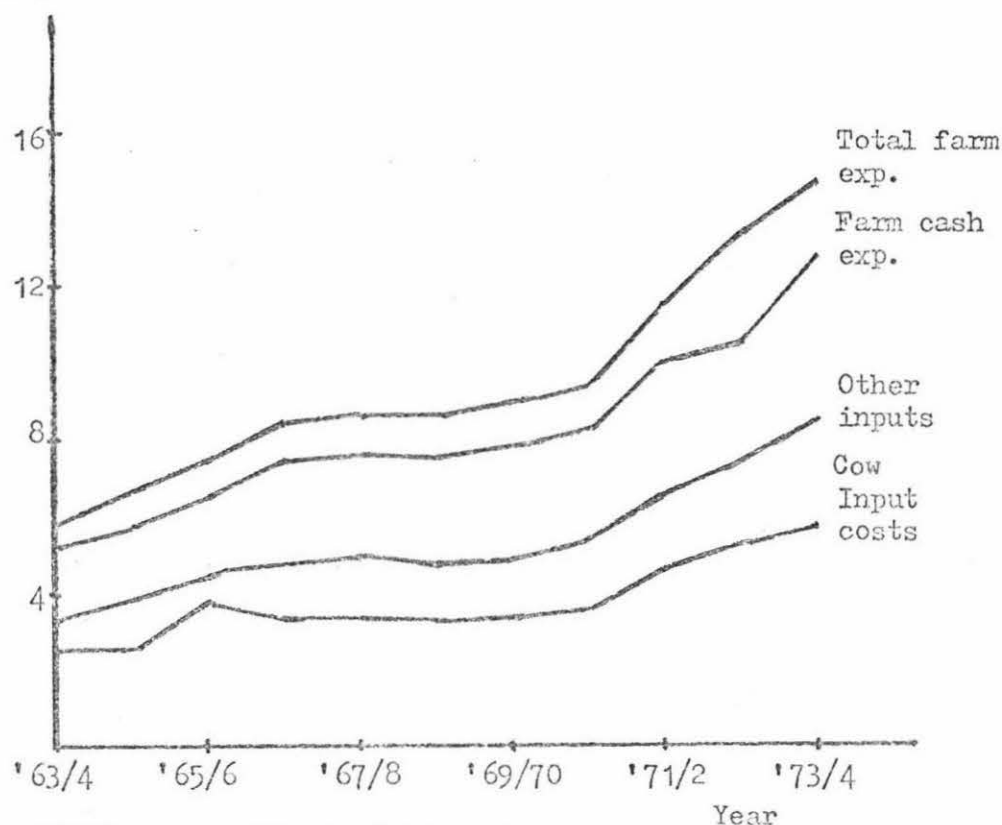
Figure 3.6:   The Components of Total Farm Expenditure

Labour on the average farm increased slightly from 1.61 units in
1963/64 to 1.69 units in 1973/74.   The majority of this labour was
family members (including the 'owner-operator'), which accounted for
83 percent of the labour in 1964/65 and 86 percent in 1972/73.   The
increased use of herringbone style milking sheds over the period of the
study* allowed the same number of labour units to handle the increased
number of cows.

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* Published information /44/ covers only farms using artificial
   breeding (AB) methods for the whole of New Zealand.   In 1963,
   10 percent of farms using AB, had herringbone sheds.   In 1972,
   this proportion had increased to 63 percent.

During the same period milkfat production per farm increased from
11 468 kg to 15 281 kg: an average increase of 2.7 percent per year.
This means that milkfat production per cow fell only slightly over the
period. Causal factors could have been the slightly higher stocking
rate, the lower level of cow inputs per cow, the weather or a combination
of these factors.

Indices of the annual changes in herd size, effective farm area,
cow inputs, labour units on the farm and milkfat production are graphed
in Figure 3.7.

3.4 A Simple Analysis of the Important Production Factors

In this section the important factors that appear to have influenced
production over the period of the study are discussed. Part of the
variation in these factors are then discussed. Finally, the effects of
changes in technology are analysed.

In the previous section, it is noted that cow inputs, cows in milk
and effective farm area expanded at a similar rate to the increase in
total milkfat production. It is also noted that changes in the weather
could have influenced milkfat production per cow over the period. A
clearer picture of the changes in the production factors and milkfat
production is obtained by considering changes in milkfat production per
cow, cow inputs per cow, cows per hectare and a variable that is thought
to take account of changes in weather. Indices of these variables are
graphed in Figure 3.8.

The variable that is thought to take account of changes in weather
is constructed from the average of the amount of rainfall that fell at
two weather stations* in Taranaki over the six months from October to
March of each season. This period is considered because the rainfall
for these months appears, on a visual examination of the data, to explain
changes in milkfat production better than other periods considered.

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* Manaia and Stratford.
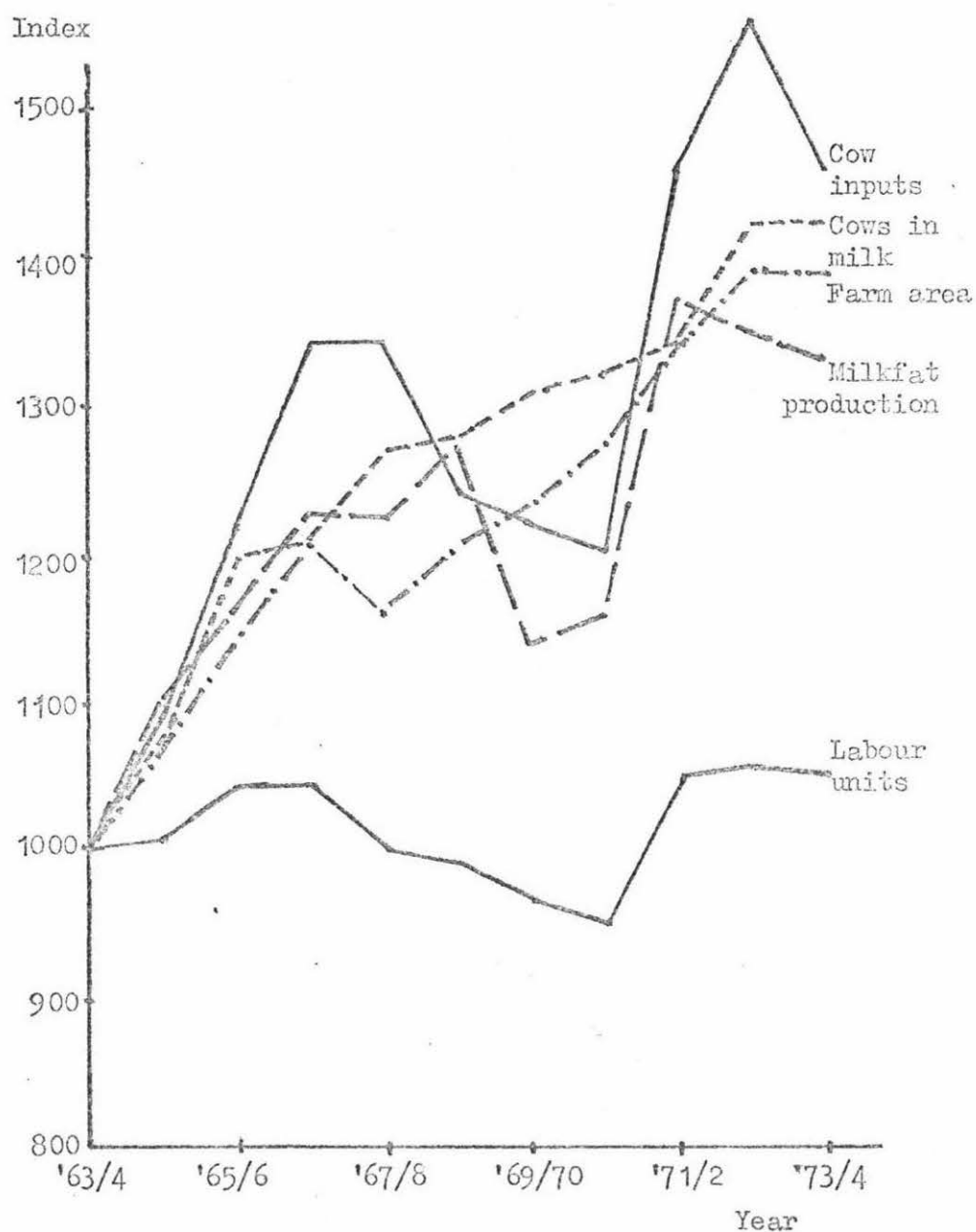
SOURCE: Appendix A, Table A.5.

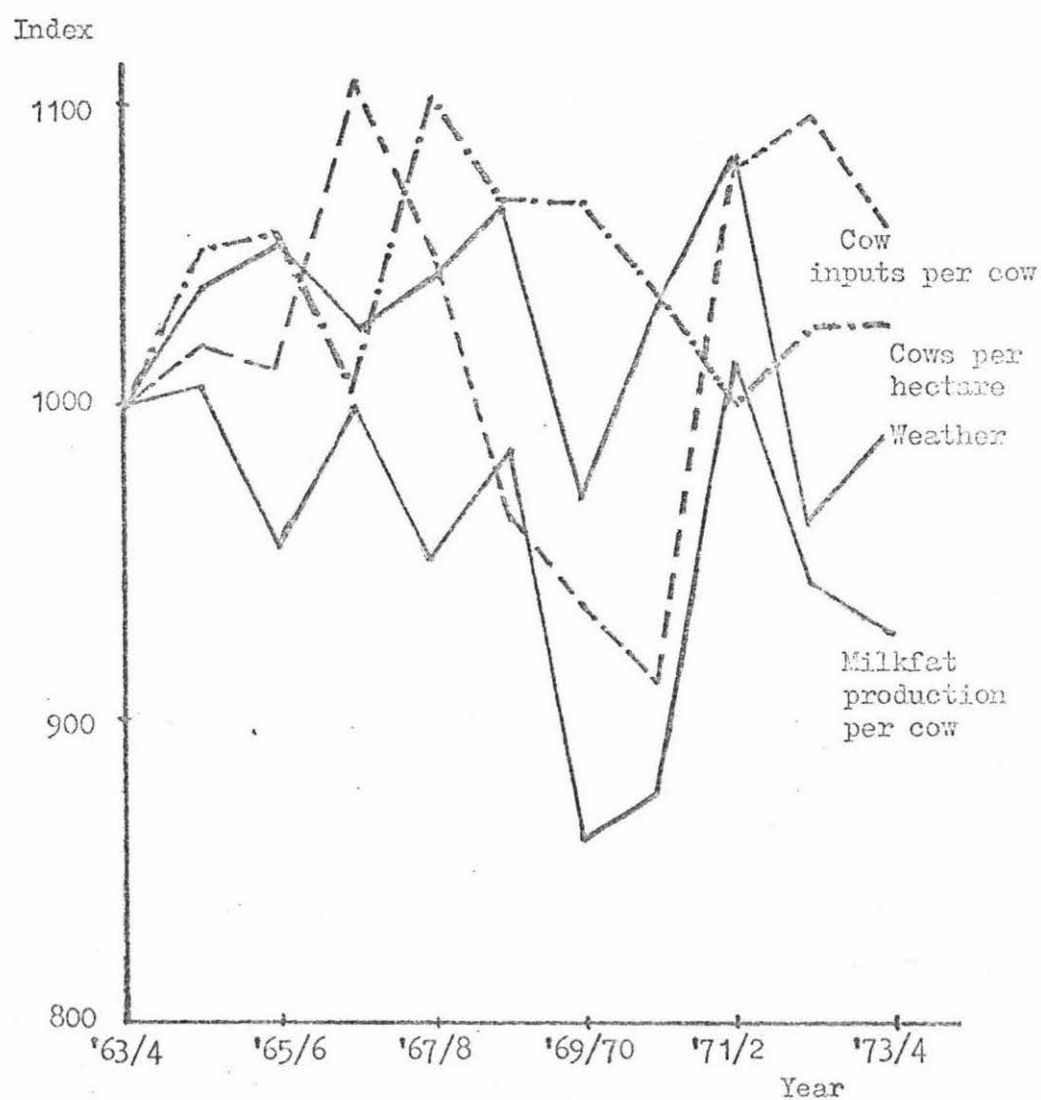Figure 3.7: Inputs and Milkfat Production Changes per Farm

SOURCE: Appendix A, Table A.6

Figure 3.8:   Input and Milkfat Production per Cow Changes

It is further thought that as the amount of rainfall increases,
production increases but at a declining rate of increase.   The
diminishing influence of rainfall is included by taking the logarithm
(to base 10) of the average rainfall over the six months.*   The
resulting series becomes the weather variable which is indexed in
Figure 3.8.

As can be noted in Figure 3.8, in most years when the weather
variable and cow inputs per cow increased, milkfat production per cow
increased.   Conversely, as the number of cows per hectare increased,
milkfat production per cow tended to decrease.

From 1963/64 to 1973/74, the average factory milk supply dairy farm
expanded production.   This expansion took place as a result of increases
in farm area, the number of cows milked and cow inputs, and occurred
over two periods.   Indices of the output prices, input prices and cow
numbers over the period from 1963/64 to 1974/75 and cow inputs from
1963/64 to 1973/74 are graphed in Figure 3.9.   As can be noted, cows
in milk and cow inputs increased in periods when output prices were
increasing faster than input prices.   In the case of cows in milk,
there appears to be a lagged response to prices.

The main feature of the Taranaki/Western Uplands region over the
period of the study is the increased use of inputs other than labour.
It is likely that the ratio of capital to labour being used in the
production process has been altered by the conversion of milking sheds
to the herringbone style $/44/$.   There has also been a gradual shift
to all grass grazing systems and the use of some purchased inputs such
as fertilizer have increased $/38/$.   These changes have allowed the
same labour force to milk the increased number of cows, but do not
appear to have influenced milkfat production per cow levels in Taranaki/
Western Uplands.

In order to test the hypothesis that changes in cow numbers,
effective farm area, cow inputs, weather and changes in technology have

* A full definition of the weather variable is given in the Notes to
Table A.6, Appendix A.
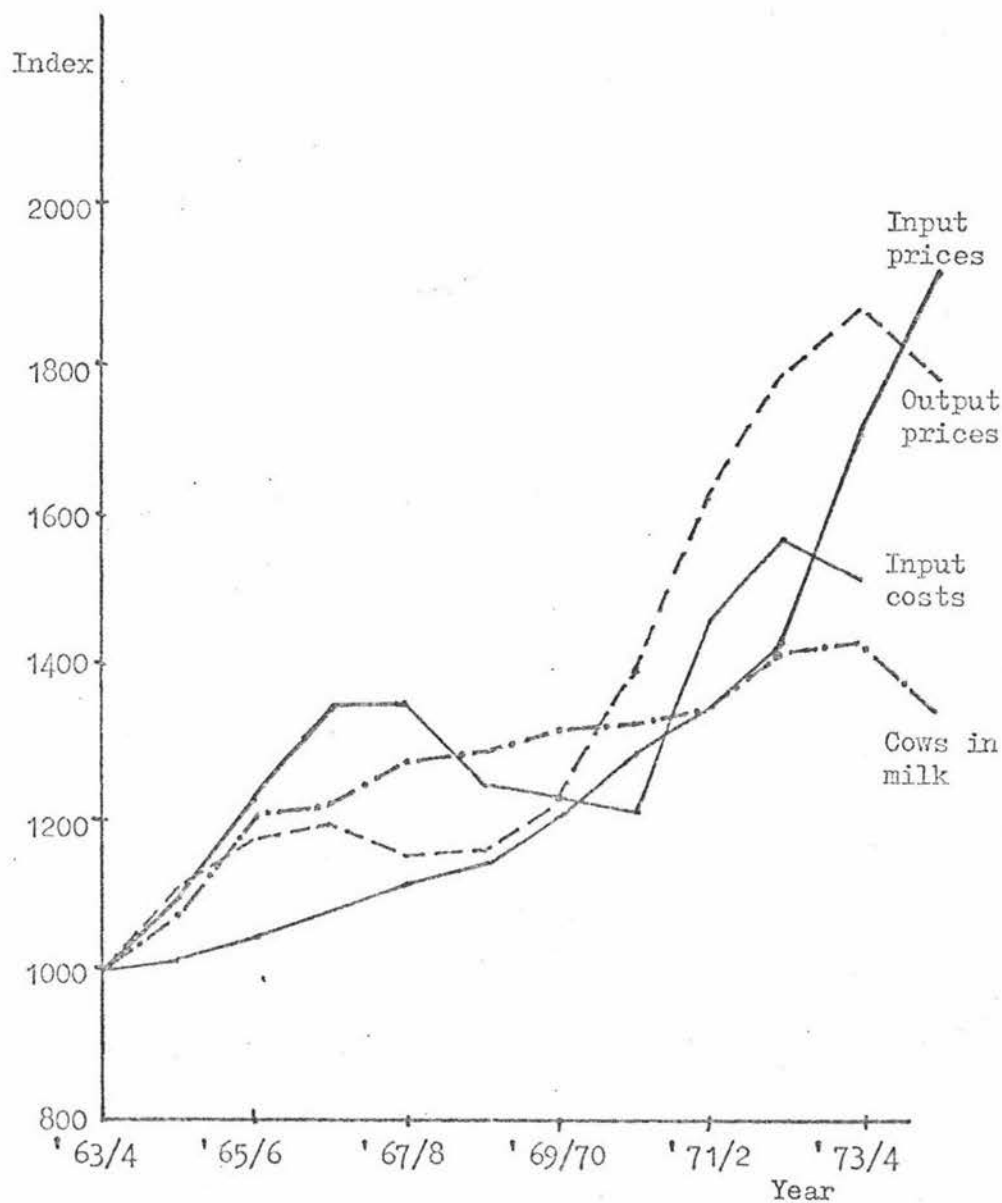
SOURCE: Appendix A, Table A.2 and Table A.5

Figure 3.9:   Changes in Some Inputs per Farm and Prices

influenced milkfat production per cow, three ordinary least squares
regressions were estimated using the data from 1963/64 to 1973/74 for
the average milk supply dairy farm in Taranaki/Western Uplands. In
all three regressions the dependent variable was milkfat production per
cow. The first regression excluded weather and a time trend variable.
The second regression excluded the time trend variable and the third
regression included all variables. The estimation and results are
discussed in Appendix B.

The best regression of changes in per cow milkfat production of
the three regressions was obtained by the exclusion of the trend
variable. The result of including the time trend indicates that some
gradual technological advances have occurred in the milkfat production
relationship. However, the estimated coefficient, which indicates that
milkfat production per cow was 0.8 percent higher each year due to
technological advances, is not significantly different from zero.

Changes in technology, however, may not have been gradual. As an
indication of technological changes in production the ratio of output to
total inputs is estimated for each year. The ratio can be represented
as a productivity index (I_t)* where:

$$I_t = \frac{p\, Q_t}{w\, L_t + r\, K_t + s\, M_t}, \text{ for } t = 1, \ldots, n;$$

where p = price of output in the base year,

$\quad Q_t$ = quantity of output in year t,

$\quad w$ = price of labour in the base year,

$\quad L_t$ = quantity of labour in year t,

$\quad r$ = price of capital in the base year,

$\quad K_t$ = quantity of capital in year t,

$\quad s$ = price of material inputs in the base year,

$\quad M_t$ = quantity of material inputs in year t, and

$\quad n$ = the number of years.

In this case $p\, Q_t$ is Total Farm Income deflated by the index of prices
received by dairy farmers and total inputs $(w L_t + r K_t + s M_t)$ is farm
expenditure deflated by the index of prices paid by dairy farmers [44].

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* Discussed in Johnson [68].

Farm expenditure is the sum of current cash expenditure, as defined
earlier, plus depreciation and thus, includes rents, rates and interest
paid.   An index of the ratio of total output to total inputs (I_t) is
shown in Figure 3.10.   Also included in Figure 3.10 is an index of
gross output.
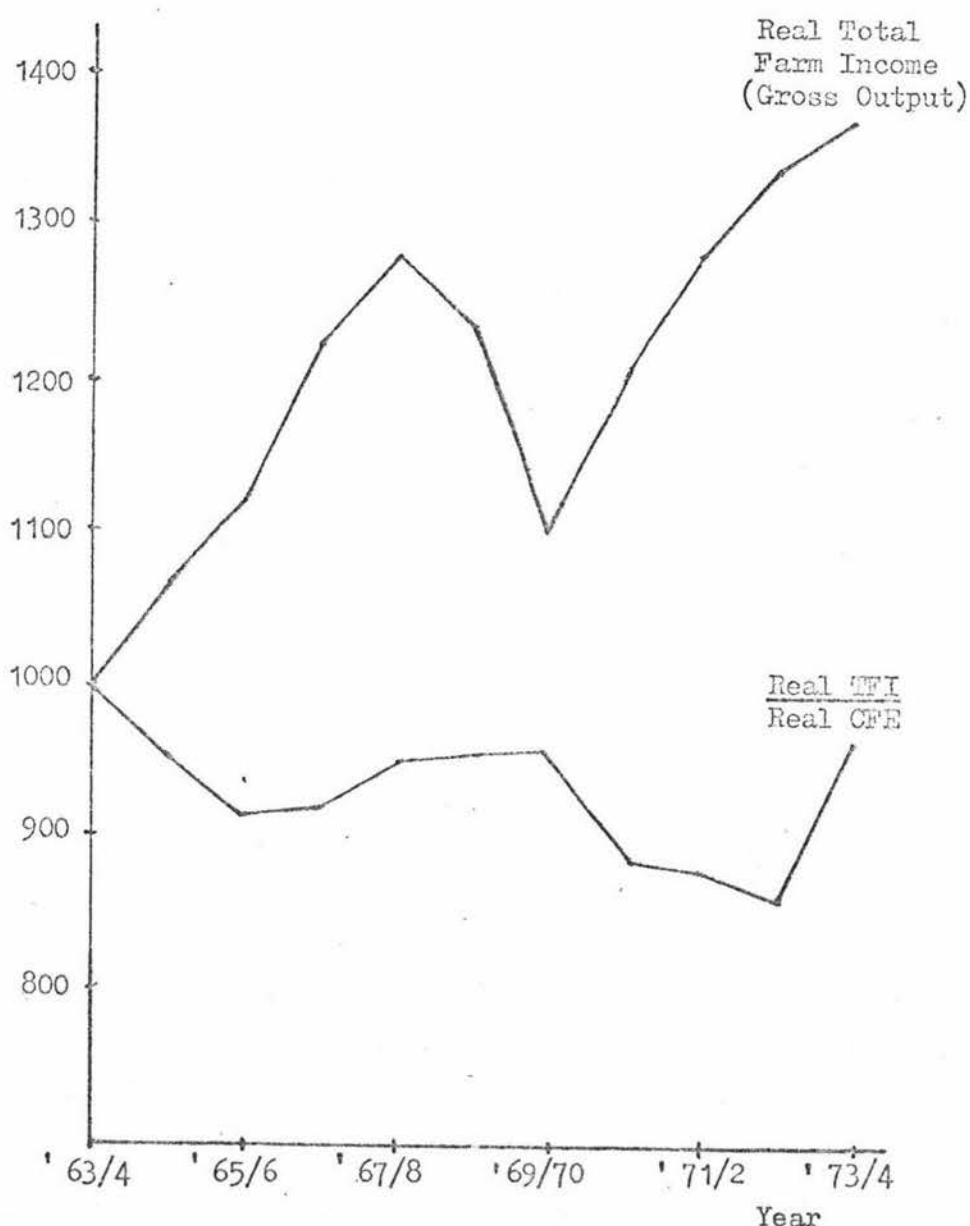
SOURCE: Appendix A, Table A.7

Figure 3.10:   The Indices of the Ratio of Real Total Farm Income (TFI)/
Real Current Farm Expenditure (CFE) and Real TFI

Because of limitations in the data the ratio (I_t), in this instance is not a perfect indicator of changes in productivity. The index of prices used to deflate expenditure on inputs does not reflect the true changes in prices (as indicated earlier). Further, the full flow of services from the capital employed in production and the farmer's own labour are not included in the inputs. Even with these errors present, I_t will have declined as a result of expansion in production as average product (which I_t measures) will have declined. On the other hand, the ratio will have increased due to a general contraction in production and/or through a technological advance.

As can be noted in Figure 3.10, the index increased over two periods when production was increasing. The two periods are from 1965/66 to 1967/68 and from 1972/73 to 1973/74. However, without an estimate of the real capital being employed over these two periods, the changes in the ratio cannot be attributed to a single cause.

One aspect of productivity trends which can be analysed is the change in factor output.* This method estimates real net output (O_t) from:

$$O_t = \frac{p\ Q_t - s\ M_t}{p} \text{ , for } t = 1, \ldots, n, \text{ and}$$

where the variables are as defined above.

From the assumption that material inputs are used up to the point where their marginal value product equals their price, it is implied that the residual is factor income. By deflating factor income by the index of prices received by dairy farmers, trends in real gross income and real factor income (factor output) can be estimated.

From 1963/64 to 1973/74 real gross income increased by 3.25 percent per year, real material inputs increased by 2.6 percent per year and factor output increased by 3.9 percent per year.** This indicates that a declining proportion of gross output went to pay for material inputs. Over the period of the study, the effective farm area expanded by an average of 3.0 percent per year while the number of labour units

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* See for example Hussey and Philpott $\lfloor 67 \rfloor$ and Johnson $\lfloor 31 \rfloor$.

** See Table A.8, Appendix A.

remained relatively constant.   Thus the weighted sum of real capital
employed, effective farm area and the number of labour units would
probably have increased by between 2 and 3 percent per year.   Therefore,
the estimated increase in factor output would tend to support the
hypothesis that the upward movements in the ratio of total output to
total inputs graphed in Figure 3.10, are partly due to changes in
technology.

3.5 Summary and Conclusions

This chapter described the changes that have occurred on the average
milk supply dairy farm in Taranaki/Western Uplands from 1963/64 to
1973/74.   A simple analysis of these changes was made using input
output ratios.

The Taranaki/Western Uplands region was chosen for this study
because of the homogeneity of the sample and because the farms in the
region produce mainly milkfat, surplus calves and cull cows.   Some bias
could be present in the sample from which the average farm was derived,
but this bias is not considered to affect this study.

Prices paid and received by dairy farmers have increased over the
period of review, but at differing rates.   The amount of price
information released to farmers has increased over the period but farmers
still only know the advance for the season at its beginning and do not
know the final amount paid until the beginning of the next season.

The region has undergone a considerable rationalisation in the
number of dairy companies with the consequence that the number of
suppliers to each company has increased.   At the same time the size of
herds has increased.

Income from milkfat has been very important, accounting for over
74 percent of income in all years.   However, its importance has declined
and the importance of income from cattle has increased.   The combined
income from milkfat, surplus calves and cattle as a proportion of total
income has increased over the period from 92 percent in 1963/64.
Farm expenditure increased substantially, but this increase was due mainly

to increased prices for some inputs such as labour.   There was a change in the input mix to labour saving devices.   The level of non-factor inputs per cow, however, remained fairly constant.   The important inputs that appear to have influenced per cow production are the number of cows, effective farm area, the level of certain non-factor inputs per cow and weather.

Farmers appear to have responded to economic stimuli.   As output prices increased faster than input prices, farmers have tended to expand production.   The analysis indicates that over the period from 1963/64 to 1973/74, the average dairy farm in Taranaki/Western Uplands, achieved substantial increases in the number of cows milked per labour unit. While this expansion may have been the farmers' overall objective, the periods when output prices increased faster than input prices, allowed farmers to use surplus cash to finance farm expansion.

This expansion has occurred by adding to farm size rather than by increasing stocking rate.   Stocking rate remained relatively constant over the period of study.   As the number of cows increased, the quantity of inputs that are thought to influence production per cow also expanded.

The reason for labour input remaining constant over the period cannot be deduced from this analysis, but given that wages accounted for 13 percent of total farm expenses in 1963/64 and had increased to 16 percent in 1973/74, and was the largest single expenditure item in all years [43_7, suggests that the rising cost of labour caused a shift to relatively more capital intensive production methods.

The change over the period of the study, to more capital intensive production methods has occurred mainly in milking methods.   However, total output per unit of inputs has remained relatively constant.   The conclusion is therefore made that some technological changes have altered the production relationships, but it is not possible in this study to determine the extent of these changes.

CHAPTER FOUR

THE DAIRY PRODUCTION AND DECISION MODEL

This chapter is a description of the model (of a dairy farm) used to project dairy cow numbers and future dairy production. The chapter describes the assumptions made, the mathematical form of the model and the manner in which projections are made.

The chapter is separated into six sections. The first section gives an overall impression of the model and an outline of the method of estimating the parameters in the model. The specific assumptions concerning the behaviour of the dairy farmer are outlined. The second section details the assumptions made in modelling the production system and the mathematical form of the functions included in the model. The decision process assumed in the model, the links between the production system and decision process and between production periods are described in the third section. The production and decision parts of the model are put together in the fourth section and the analytical derivation of the variables under the farmer's control are described. The fifth section outlines two methods of making projections and the overall model is summarised in the sixth section.

Many assumptions are made in this chapter to facilitate the building of the model. The assumptions are made firstly so that the model describes in a simplified manner the farming system under study and the major changes that have occurred in the system. Secondly, the assumptions are made so that a relatively simple model can be built that can be solved analytically for the important variables that influence future stock numbers.

The aim (in making the assumptions) is to build a model that exhibits increasing returns but at a diminishing rate of increase as the level of inputs increase. As output increases, costs are assumed to rise at an increasing rate. These responses are assumed to be quadratic in nature (or can be described by quadratic functions) and as

output increases revenue and costs change as shown in Figure 4.1 (a).

From the revenue and costs functions a net revenue function is derived which changes as indicated in Figure 4.1 (b) by the line OBC. The many assumptions made in building the model allows the output level that maximises OBC (point A in Figure 4.1) to be obtained analytically. The level of inputs that produce the quantity of output at A is then estimated.

The model must also estimate the level of expected net revenue over a number of years. This level of net revenue must be consistent with the farmer's time preference for income. The level of net revenue in one year is influenced by the expected level in the next year since farming, as with most enterprises, is dynamic in that decisions made each year influence future levels of output. Thus the model estimates the planned input levels for each year that yield the desired net revenue stream through time.

4.1 The Model

This model is the combination of a model of a production system and the dairy farmer's decision process. The aim in building the model is to represent the dairy farming system.

The production model is a conventional output response model; the output level changes in response to varying intensities of input applications. These output changes are dependent on production parameters, the number of stock carried, the farm area, and the level of certain inputs under the farmer's control. The variables that the farmer controls directly are termed decision variables, and link the production and decision processes.

There are many variables that the dairy farmer will control in the real world. For purposes of simplification, those included in the model are the number of cows to cull from the milking herd, the number of female calves to rear and the quantity of variable inputs that influence per cow performance. The important omission from this list of decision variables is the area of land available to the milking cows.
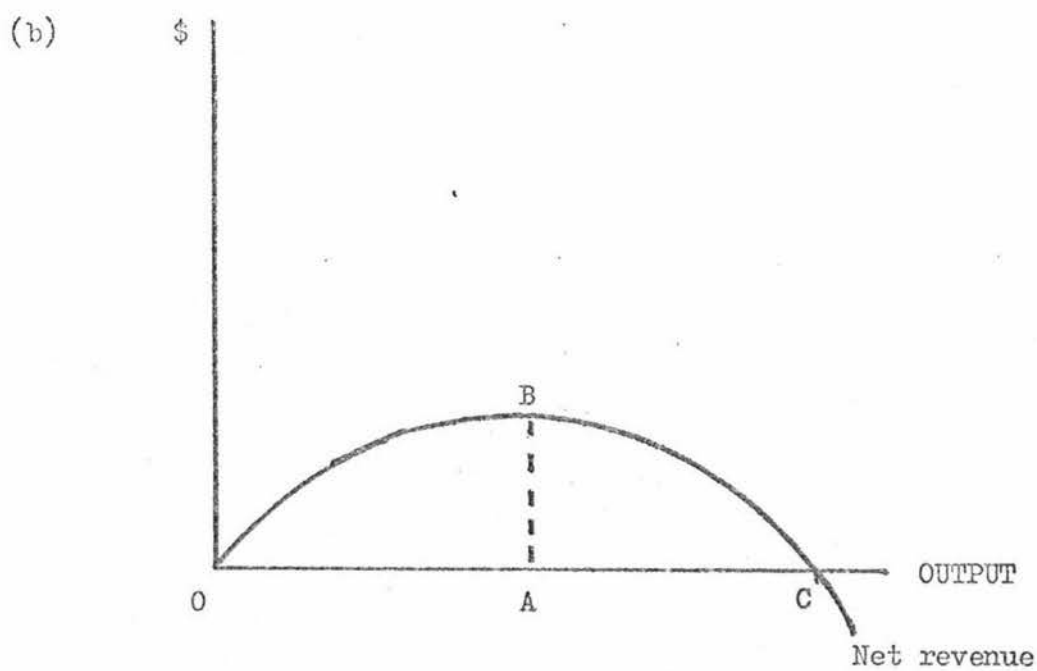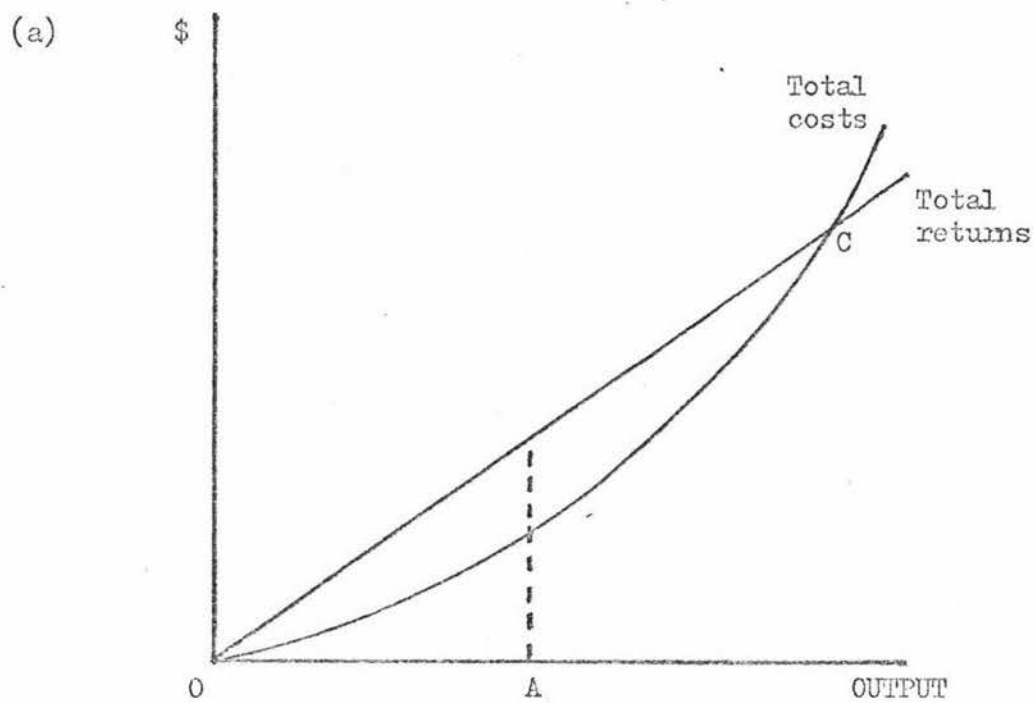
Figure 4.1: Total Returns and Costs in Response to Output Changes

Land is included in the model as an input variable by assuming that
for the planning horizon, the effective farm area will continue to change
by the same amount as it changed from the previous season.   The
inclusion of effective farm area is extremely important because, as
indicated in Chapter Three, effective farm area has expanded over the
period of the study at the same rate as the number of cows.   It is also
important as a decision variable and should be included in the model.
However, the inclusion of effective farm area as a decision variable to
be solved for would make an analytical solution extremely difficult.

In the decision model the dairy farmer is assumed to make a plan
each year, based on the farmer's current state of knowledge, current
stock numbers and his expectations concerning future prices.   Each
year he will plan to change from his current situation and will begin
to move towards an 'optimum'.   He will adjust stock numbers and other
inputs in the current year.   In future years he will envisage changing
the variables so as to attain the 'optimum' in m years time.   In this
study the 'optimum' plan is where the capitalised expected future income
stream is maximized.   As the farmer's expectation of future prices and
his knowledge change, his 'optimum' plan will change.   Thus the
envisaged future input and output levels will not be those realised.
Instead the farmer will alter input levels in line with his new plan.

The dynamics of the model are represented in Figure 4.2 where two
years are shown to indicate the relationships.   Output in each year is
determined by the level of inputs.   By retaining stock for future years,
the farmer is investing in future income.   The rate at which he invests
in future income will depend on his time preference for income.   His
time preference for income determines the rate at which he discounts
future income, which determines the number of stock to retain at the
end of the year.

In the following two sections, relationships are developed to
explain the envisaged future output and input levels.   These inter-year
functions are stock reconciliations, decision relationships and price
expectation functions.   The stock reconciliations allow envisaged
future stock numbers to be expressed in terms of current year stock
numbers.   The inter-year decision relationships allow envisaged levels
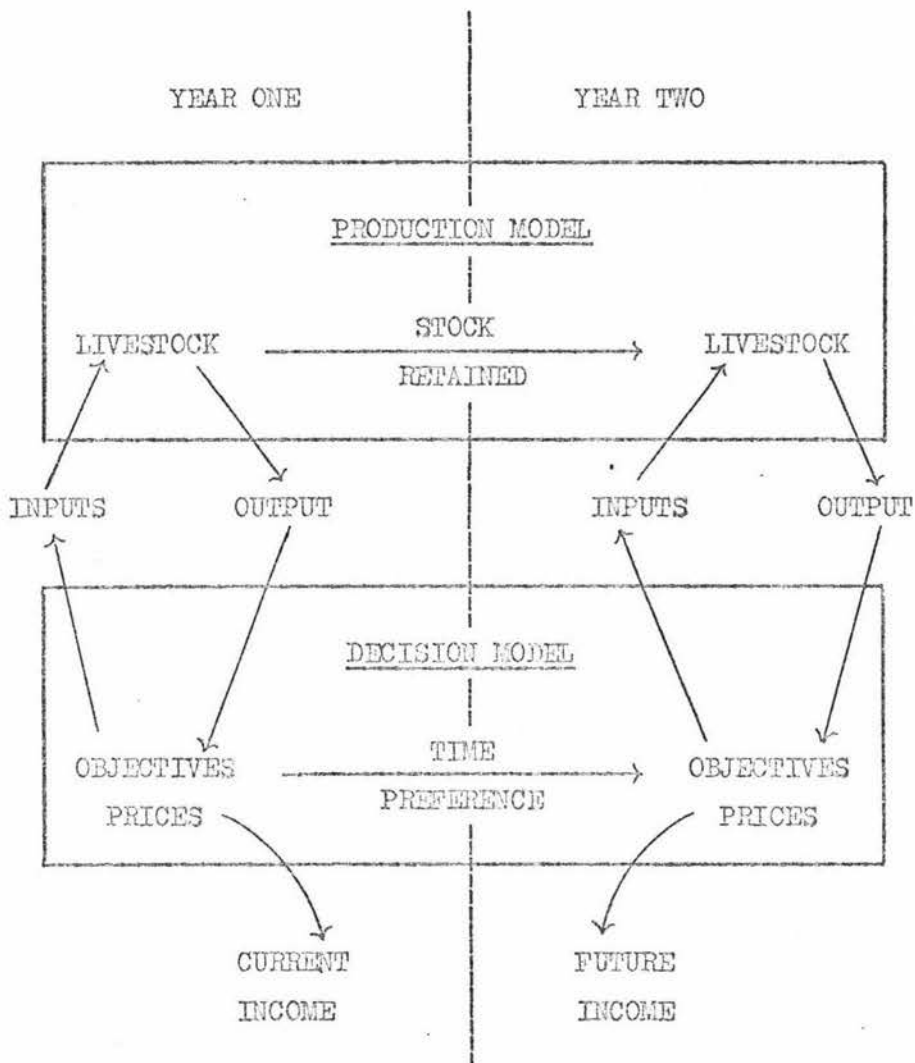
Figure 4.2:   A Dynamic Representation for Two Years of the Farming System

of decision variables to be expressed in terms of current decisions and
the price expectation functions express expected prices in terms of
known prices.   These relationships allow envisaged future income to
be expressed in terms of current and known variables and each year's
envisaged income is linked together by the discount rates.   Thus the
expected future income stream can be expressed in terms of current
and known variables.

In building the model, functional forms of the relationships are
assumed and parameters inserted.   These parameters are assumed to be
constant over the period of the study and need to be estimated.   As
indicated in Figure 4.3 the parameters are preset and the model is
solved for the decision variables.   These decision variables are then
compared with those derived from the actual data and the parameters
adjusted until the estimated decision variables are as close as possible
to the actuals.   The model can then be used to project future output
and input levels.
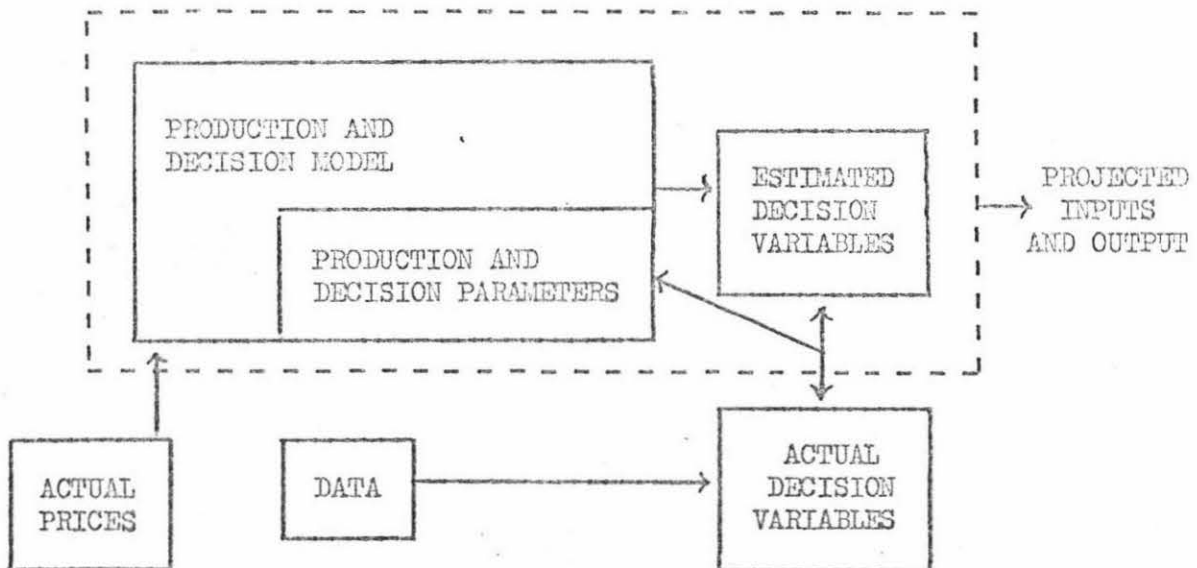
$\longrightarrow$ indicates the direction of estimation and influence
$\longleftrightarrow$ indicates a comparison

Figure 4.3:   Estimation Procedure

4.2 The Production Model

The production model is concerned with the physical effects of changing levels of input on output and costs. In a dynamic sense the production model is concerned with the spread of output between years through the retention of stock. The variables that are assumed to influence production are the number of cows in milk (CM), the effective farm area (A) and the inputs that influence per cow performance (IC).

Output is composed of milkfat produced (MP), surplus calves (B) and cull cows (C). In practise, some heifers available to be milked, could be culled. In the model these are assumed to be an insignificant number and are ignored. Other sources of income on the dairy farm are also ignored to keep the model relatively simple.

The costs are split into three groups. The most important are the costs of the inputs that influence per cow performance and are termed 'cow input costs'.* Other costs such as labour and dairy shed expenses will vary as a result of changes in cow numbers and these are termed 'milking costs'. Some costs such as grazing expenses will vary in response to changes in the number of heifers held. These are termed 'heifer costs'.

The dairy farmer is in business to produce an income. The combined affects of the inputs, output and costs on income is shown diagrammatically in Figure 4.4. The prices are constant for each year and independent of the level of output or input.

This section explains the assumptions made in building the production model and the exact mathematical forms of the relationships. The model is built on the assumption that managerial ability has not changed over the period of the study and that changes in technology have not affected the production relationships. It is further

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* The term 'cow input costs' differentiates the costs from those affected by output. The quantity of these inputs are termed 'cow inputs'(IC).
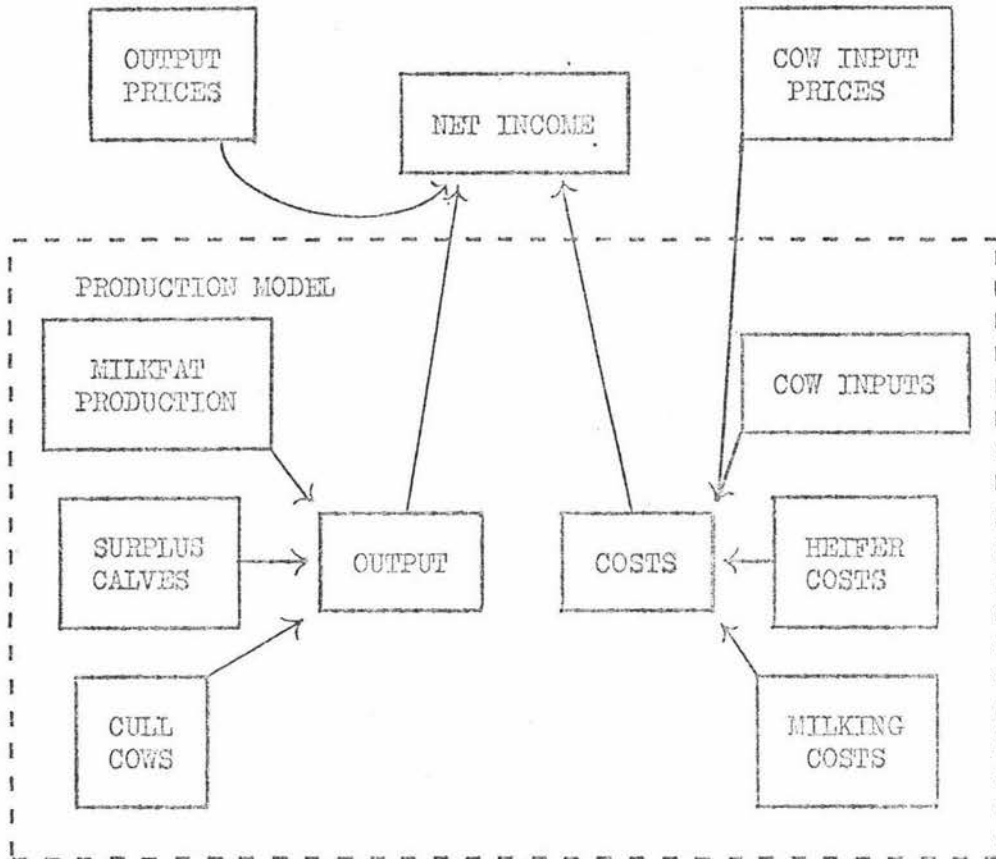
The lines indicate the directions of influence

Figure 4.4:   The Combination of Outputs and Inputs in the Production
              Model

assumed that the average farm, which the model is being built to
describe, was drawn from a sample in which the level of technology,
managerial ability and the levels of inputs were independent.

The variables that the farmer adjusts in order to alter output
levels are discussed in the section on the decision process.

4.2.1 Milk production

The quantity of milkfat produced* is assumed to be dependent on the number of cows milked and the average quantity of milkfat produced per cow. The quantity of milkfat produced per cow is dependent on the amount of feed available per cow, which in turn is dependent on the amount of inputs used to produce grass and the effective farm area. The following equation describes the manner in which the factors are assumed to affect milkfat production, and the section in parenthesis is the average milkfat production per cow.

$$MP_t = CM_t \left(e_1 - e_2 \frac{CM_t}{A_t} + e_3 \frac{IC_t}{CM_t} - e_4 \frac{IC_t^2}{CM_t} \right) \qquad (4.2.1)$$

for $t = 1, \ldots, \infty$, and

where $e_1, \ldots, e_4$ are production parameters.

The milkfat production equation does not take changes in weather into account. The effects of changing input levels on milkfat production per cow are indicated in Appendix B.

4.2.2 Surplus calves

Two simplifying assumptions are made to incorporate the production of calves and the sale of surplus calves. Firstly, the number of calves born that survive to sale are assumed to equal the number of cows milked in January of that season. Secondly, any male calves reared to be sold as weaners for beef production are assumed not to compete with the cows in milk for inputs and hence not to influence the farmer's decisions concerning the number of cows to milk. These two assumptions allow the number of surplus calves sold each year to be expressed as the balance of the calves born minus the female calves

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* The solid-not-fat (SNF) portion of milk is assumed to be a constant proportion of the milkfat content of the milk and so a discussion of milkfat includes the SNF portion.

reared for replacement purposes. By simplification, the number of surplus calves (B) becomes:

$$B_t = CM_t - FC_t \; ; \; t = 1, \; \ldots, \infty, \text{ and} \qquad (4.2.2)$$

where FC_t = the number of female calves reared.

4.2.3 Milking costs

As cow numbers increase the cost of certain items such as labour, freight and dairy shed expenses are assumed to increase at an increasing rate. Generally, the addition of some input items such as the addition of an extra labour unit, is lumpy in relation to total use. But given small increases in cow numbers, labour, for example, can be increased gradually by the employment of casual labour at milking times or weekends.

The following equation has been used to model the effects of changing cow numbers on milking costs:

$$MC_t = CM_t \, (a_1 + a_2 \, CM_t) \; ; \quad t = 1, \; \ldots, \infty, \text{ and} \quad (4.2.3)$$

where a_1 = fixed costs per cow,
a_2 = a constant,
$a_2 \, CM$ = variable costs per cow, and
MC = milking cost.

The changes in MC as CM change are indicated in Figure 4.5.

4.2.4 Heifer costs

The number of heifers retained as replacements (H) will influence grazing, mating and handling costs. If the heifers are grazed on the farm the cost will be in terms of the opportunity cost of milk production.* Fixed costs associated with holding heifers are assumed

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* For example, if the heifers are grazed on the farm the cost may be a decrease in milkfat production.

Milking
cost
($)

Slope =
$a_1 + 2a_2CM$

0

No. of Cows
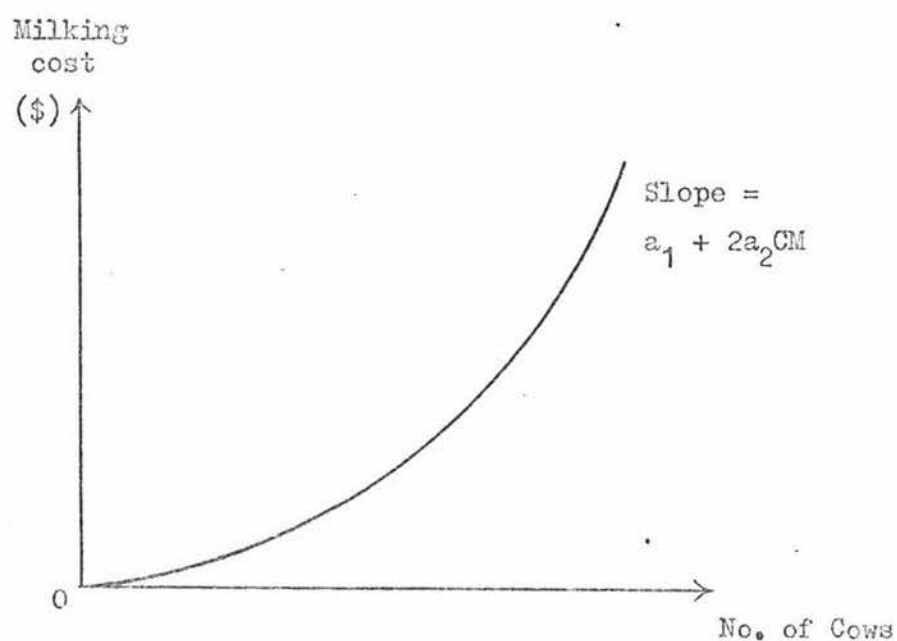
Figure 4.5:   The Effects of Changing Cow Numbers on Milking Costs

Heifer
cost
($)

Slope =
$2bH$

0

No. of
heifers
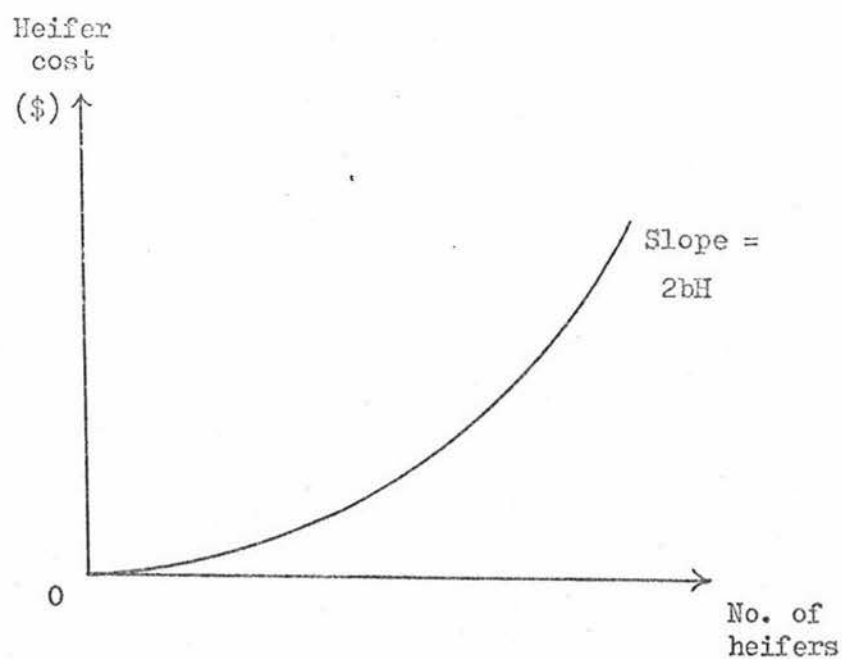
Figure 4.6:   The Effects of Changing Heifer Numbers on Heifer Costs

to be negligible and are ignored. The equation that takes account of changes in heifer costs (HC) as H changes is:

$$HC_t = bH_t^2 \; ; \; t = 1, \ldots, \infty, \text{ and } b = \text{a constant.} \qquad (4.2.4)$$

The effect of varying H on HC is indicated in Figure 4.6.

4.2.5 Stock reconciliations

All available cows are assumed to be milked during the season and all cullings occur at the end of the milk production period. It is recognised that in practise some culling will occur during the season, but to simplify the model this has been ignored. The farmer is assumed to milk all heifers that survive from the previous season and calve, in preference to retaining an older cow due for retirement.

Thus the number of cows milked each year is the reconciliation of the cows that survive from the previous season, the number of heifers available in the current season and the number of cows culled at the end of the previous season. That is:

$$CM_t = \gamma_1 \, CM_{t-1} + \gamma_2 H_{t-1} - C_{t-1} \; : \; t = 1, \ldots, \infty, \text{ and} \qquad (4.2.5)$$

where γ_1 = the survival rate of cows in milk,

γ_2 = the survival and calving rate of heifers.

The number of heifers held in any year (H) is assumed to be those female calves (FC) that survive from the previous season. That is:

$$H_t = \gamma_3 \, FC_{t-1} \; ; \; t = 1, \ldots, \infty, \text{ and} \qquad (4.2.6)$$

where γ_3 = the survival rate of female calves.

4.2.6 Farm area

Over the period of the study effective farm area has expanded.
In order to take this expansion into account the area of the farm (A)
is assumed to alter over the planning horizon by the amount that it
has changed from the previous season as follows:

$$A_t^* = A_{t-1} + (A_{t-1} - A_{t-2}) \; ; \; t = 2, \; ..., \; m, \qquad (4.2.7)$$

where m = the end of the planning horizon, and
A_t^* = the envisaged farm area.

After year m the farm area is assumed to remain constant.

4.3 The Model of the Decision Process

The decision process assumed for this model is that the farmer
has a planning horizon of m years over which he plans to adjust stock
numbers and input levels so as to attain an 'optimum' farm situation.
The important variables that the farmer can adjust are termed
decision variables and are discussed in the first part of this section.
The 'optimum' plan is where the capitalised future expected income
stream is maximized. The exact form of including each years expected
income in the objective function is discussed in the second part of
this section. The third part deals with the assumed process of
forming price expectations.

4.3.1 Decision variables

In the production model the farmer has several variables under his
control which he can adjust to influence future cow numbers. The
variables that directly affect the number of cows milked are the
number of heifers entering the herd and the number of cows being culled.
In this model all the available heifers are assumed to enter the herd.
The decision concerning the number of heifers available is made in the
previous year when the farmer decides the number of female calves to
rear. The decision concerning the number of cows to cull is assumed
to be made at the end of the production period. This decision

is based on the desired number of cows to milk in the following season.

The second type of decision variable concerns the level of inputs that affect per cow performance and are termed "cow inputs" (IC). The level of these inputs is indirectly related to the number of stock carried. Even so, they form an important part of the production and decision processes as indicated in Chapter 2, and cannot be ignored in this model. A full listing of the inputs included in IC is given in Table A4 in Appendix A. Each unit of input is assumed to have the same influence on output. While the effect of different inputs varies in the real world, the aim is to represent the overall effect of changing input levels. The inclusion of individual inputs in the model is not possible in this study.

The investment decisions the farmer makes in each year will influence future stock numbers and, in this model, the decisions are based on the farmer's 'optimum' future stock levels. In the current year the farmer plans to make future decisions. In order to avoid the necessity of solving for, in this case, 3 decision variables for each of the m years, the intervening year's decisions are assumed to take a specific form. The assumption is made that the envisaged decisions will depend on the current years decision but are adjusted for envisaged changes in the number of cows milked.

The envisaged number of cows to be culled in future years is given by:

$$C^*_{t+1} = \alpha_1 C_t + \alpha_2(CM^*_{t+1} - CM_t) \; ; \; t = 1, \ldots, m-1 \qquad (4.3.1)$$

where α_1 and α_2 are constants,

and * indicates an envisaged level of a variable.

In year m the number of cows culled in order to maintain a stable herd size from year m to ∞, will be the surplus from the heifers available minus the cows that died. That is:

$$C^*_m = \gamma_2 H^*_{m-1} - (1 - \gamma_1) CM^*_m \qquad (4.3.2)$$

The number of calves envisaged as being reared in future years is modelled as:

$$FC^*_{t+1} = \delta_1 FC_t + \delta_2(CM^*_{t+1} - CM_t) \; ; \; t = 1, \ldots, m-2, \quad (4.3.3)$$

where δ_1 and δ_2 are constants to be estimated.

In years m-1 and m the envisaged number of female calves to rear is assumed to remain constant at the number reared in year m-2, in order to maintain a stable herd size from year m onwards. That is:

$$FC^*_m = FC^*_{m-1} = FC^*_{m-2} \quad (4.3.4)$$

The level of cow inputs is assumed to depend on the level the previous year and the envisaged changes in cow numbers between years, up to year m. That is:

$$IC^*_{t+1} = Q_1 IC_t + Q_2(CM^*_{t+1} - CM_t) \; ; \; t = 1, \ldots, m, \quad (4.3.5)$$

where Q_1 and Q_2 are constants to be estimated.

In all cases, in the year after the plan is made the current year variables become envisaged variables.

4.3.2 The objectives of the dairy farmer

The hypothesis put forward is that the dairy farmer makes decisions each year with the intention that in m years time he will milk an 'optimum' number of cows. The 'optimum' plan is assumed to be where the present value of the expected future income stream is maximised. To allow for the farmer's time preference for income, the expected income for each year up to year m is discounted and the income in year m capitalised and the capital value discounted. Because of the possibility that the dairy farmer's time preference may not follow the pattern explained by a constant interest rate, a variable discount rate for each year is incorporated into the model.

The objective function to be maximized, is expressed·for year k as:

Maximize Z_k;

where

$$Z_k = Y_k + Y^*_{k+1} d_2 + \dots + Y^*_{k+m-1} d_m \; ; \qquad (4.3.6)$$

$Y^*_t = $ the envisaged income in year t,

$k = $ the year the plan is made,

$d_2, \dots, d_m$ are the discount rates, and

d_m is the capitalising discount rate.

In year k+1 the plan will alter if prices change since the farmer will expect a different income stream. The new Z in year k+1 is given by:

$$Z_{k+1} = Y_{k+1} + Y^{**}_{k+2} d_2 + \dots + Y^{**}_{k+m} d_m \; ;$$

where ** indicates the new envisaged income.

4.3.3 Price expectations

Envisaged future income is influenced by the prices the farmer expects to receive in future years. In line with the information presented in Chapter 2, it is assumed that the farmer projects simple trends through known prices. The assumed process is that the following season's price will change by some proportion of the amount by which it changes from the previous season. That is:

$$P^*_{t+1} = P_t + g(P_t - P_{t-1}) \; ; \quad t = 1, \dots, m-1, \text{ and} \qquad (4.3.7)$$

where $P = $ known price,

$P^* = $ the expected price,

$g = $ a constant.

The formation of the expected prices will differ for the various price series in the model depending on g. The setting of g is discussed in the following chapter.

4.4 The Overall Model

The overall model links together the production and decision processes. The production process is made up from input/output relationships and stock reconciliations. The decision process aims to maximize net revenue over time in a manner that reflects the dairy farmer's desire for future income.

Under the assumptions outlined in the previous two sections, the envisaged future income stream can be expressed in terms of the current year's stock numbers, decision variables, production parameters and known prices. The expressions that allow this are the stock reconciliations, inter year decision relationships and the price expectation functions. The parameters are assumed to remain constant over the planning horizon.

The farmer's discount rates link each year's income, allowing the farmer's objective function (Z) to be expressed in terms of known data and production parameters. Since each decision variable for the current year is present in Z, it is a matter of solving the first partial derivatives of Z for the decision variables that maximize Z. The necessary and sufficient conditions for Z to be a maximum are that the first partial derivatives of Z with respect to the decision variables are equal to zero and that the matrix of second partial derivatives is negative definite $\underline{/}$1, pp.495-500$\underline{/}$. Further, the system of first partial derivatives must be of such a form that the decision variables can be solved.

These estimated decision variables can then be used to project future stock numbers. The process of obtaining the decision variables is indicated diagrammatically in Figure 4.7.

Mathematically the procedure can be expressed as:

Maximise

$$Z = Y_1 + d_2 Y_2^* + d_3 Y_3^* + \ldots + d_m Y_m^* \qquad (4.4.1)$$

where $d_2 \ldots d_m$ are as defined earlier, and
Z = the present value of future net income.
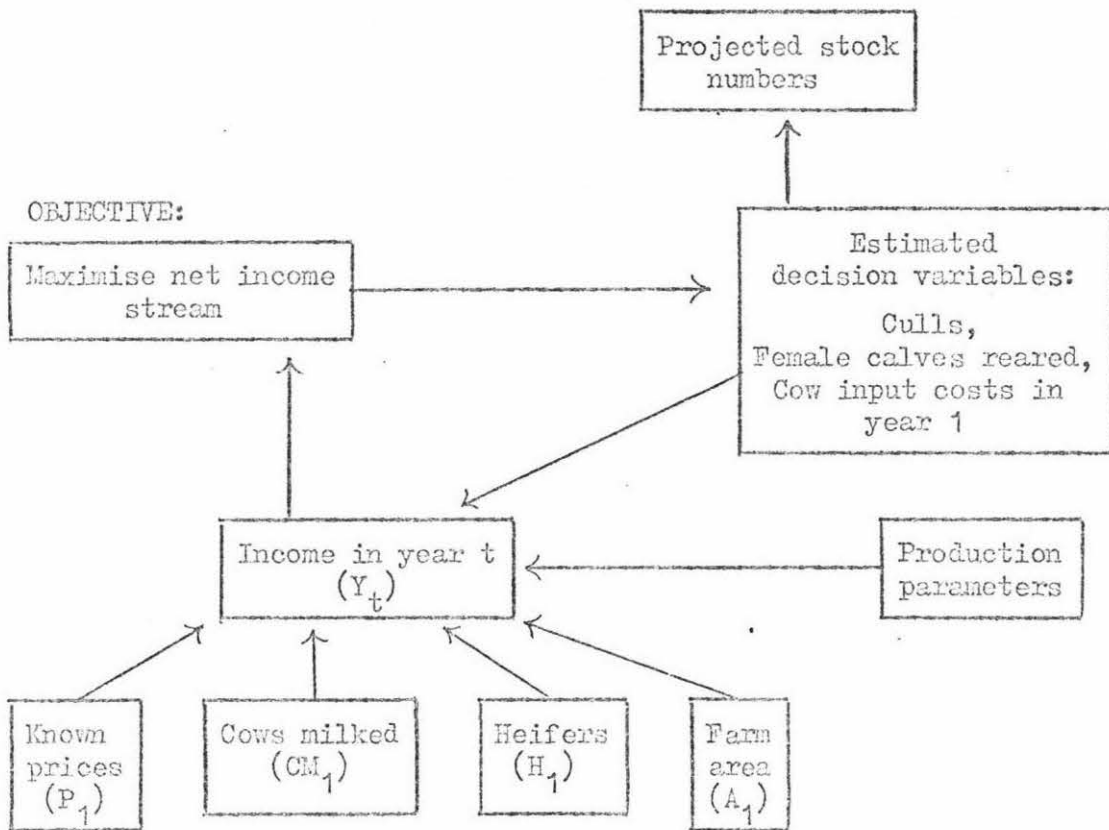
where the arrows indicate directions of estimation

Figure 4.7:   The Overall Model

Each year's income,

$$Y_t^* = f(SN_t, DV_t, P_t^*, \sigma) \; ;$$

for $t = 1, \ldots, m$

where σ = production parameters

f is a specified function,

SN = stock numbers,

DV = decision variables,

P* = expected prices.

By substituting the intervening year's functions and price expectations into Y_t^*, Y_t^* can be expressed as:

$$Y_t^* = f^t(SN_1, DV_1, P_1, \sigma); \qquad (4.4.2)$$

for $t = 1, \ldots, m$

where f^t is a specified function for each t derived from the substitution.

This then allows the objective function (4.4.1) to be expressed as:

$$Z = z(SN_1, DV_1, P_1, \sigma); \qquad (4.4.3)$$

where z is a function derived from the substitution of (4.4.2) into (4.4.1).

Z is maximised where the partial derivatives of Z with respect to the decision variables, are set equal to zero (it is assumed that the matrix of second partial derivatives is negative definite).

$$\frac{\partial Z}{\partial DV_1} = D.DV_1 - E = 0 ; \qquad (4.4.4)$$

where D is a matrix such that
$$D = d(SN_1, P_1, \sigma) ;$$

where d is a specified function derived from the partial differentiation of (4.4.3), and E is a vector such that

$$E = e(SN_1, P_1, \sigma) ;$$

where e is a specified function derived from the partial differentiation of (4.4.3).

The system (4.4.4) can be solved for the decision variables by inverting D and post multiplying D by E:

$$DV_1 = D^{-1} E.$$

4.5 The Projection Methods

The following briefly sets out two methods of making projections using the model. The projection procedures used are discussed fully in Chapter 5.

After estimation of the parameters in the model, the decision variables that maximize Z can be calculated and projections made using these decision variables. There are two simple methods of making projections using this model.

The first and simplest method is to project m years ahead on the basis that the farmer carries his envisaged plan through. This type of projection would indicate the direction in which the farm is moving. In Figure 4.8, the solid line indicates this first type of projection.

The second method is to project one year ahead using known prices and continue to project one year ahead using prices that are projected outside the model. This process can be continued for as many years as prices are available. The projections made by this second method are represented by the dashed and dot-dashed lines in Figure 4.8.

The projection using known prices will contain an error due to the model. In subsequent years the projections will contain errors due to the price projections as well as the model. These errors will increase as the number of years for which the projections are made increases. Thus, the range of possible future stock numbers will increase accordingly.

4.6 Summary

In this chapter a model of the production and decision processes were outlined. The basis of the model is that the dairy farmer is assumed to plan each year in order to attain an 'optimum' situation m years ahead, using his expectation of future prices and his current state of knowledge. Each year after he has made a plan, the farmer is assumed to change it in the light of new information. .

Cow
numbers

0   1   2   3   4   years
ahead
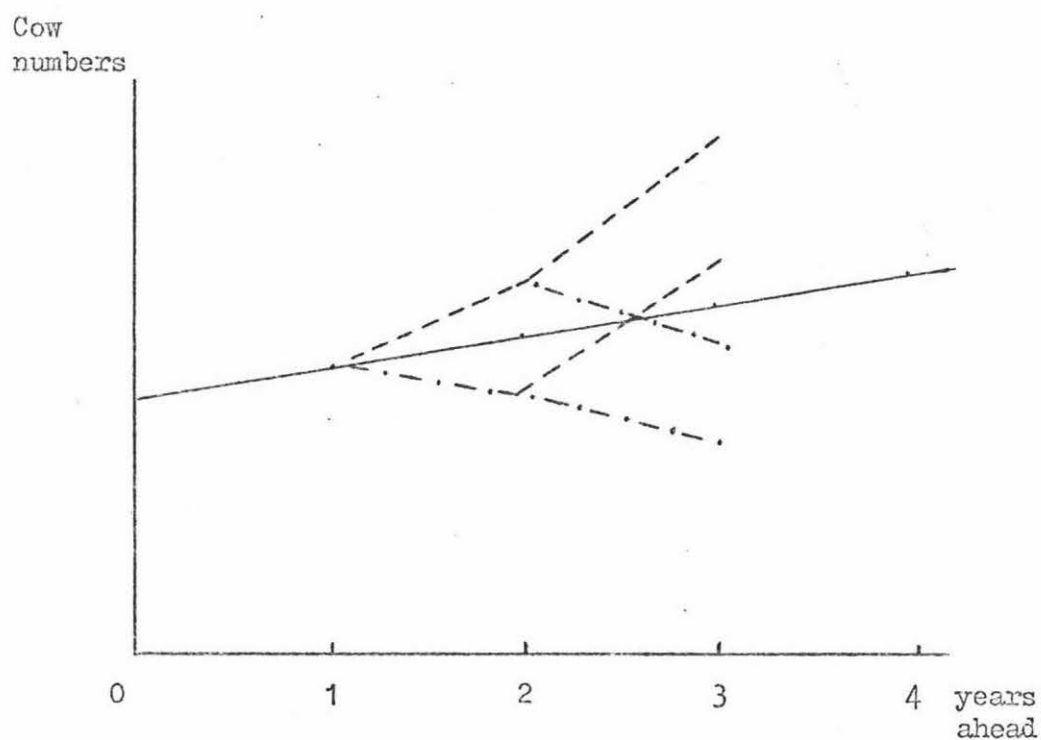
NOTE: ——— indicates a 4 year projection

– – – indicates a projection one year ahead using favourable prices

·—·— indicates a projection one year ahead using unfavourable prices

Figure 4.8:   Two Projection Methods

$$Z = Y_k + d_2 \, Y^*_{k+1} + d_3 \, Y^*_{k+2} + \ldots, + d_m \, Y^*_{k+m-1} , \qquad (4.3.6)$$

where k = the year the plan is made

$d_2, \ldots, d_m$ are discount rates,

Y = net income,

Y^* = envisaged net income, and

m = the farmer's planning horizon.

Net income is:

$$Y = Pm \; MP + Pb \; B + Pc \; C - MC - HC - PI \; IC ,$$

where Pm = the price of milkfat,

Pb = the price of surplus calves,

Pc = the price of cull cows, and

PI = the index of prices of inputs.

Envisaged income is constructed using price expectation functions of the general form:

$$P^*_t = P_{t-1} + g(P_{t-1} - P_{t-2}), \qquad (4.3.7)$$

where P are actual prices,

P^* is the expected price, and

g = a constant.

The decision variables (C, FC and IC) are assumed to be envisaged as changing in a particular manner for each variable within the planning horizon. These relationships are as follows:

$$C^*_{t+1} = \alpha_1 \, C_t + \alpha_2 \, (CM^*_{t+1} - CM_t); \quad \text{for } t = 1, \ldots, m-2, \text{ and } (4.3.1)$$

$$C^*_m = \gamma_2 \, H^*_{m-1} - (1 - \gamma_1) \, CM^*_m , \qquad (4.3.2)$$

$$FC^*_{t+1} = \delta_1 \, FC_t + \delta_2 \, (CM^*_{t+1} - CM_t); \quad \text{for } t = 1, \ldots, m-3, \text{ and } (4.3.3)$$

$$FC^*_m = FC^*_{m-1} = FC^*_{m-2} , \qquad (4.3.4)$$

$$IC^*_{t+1} = Q_1 \, IC_t + Q_2 \, (CM^*_{t+1} - CM_t); \quad \text{for } t = 1, \ldots, m-1, \quad (4.3.5)$$

where * indicates envisaged or expected variables and

$$\alpha_1, \alpha_2, \delta_1, \delta_2, Q_1, \text{ and } Q_2 \text{ are constants.}$$

Farm area (A) is assumed to expand over the planning horizon by:

$$A^*_{t+1} = A_t + (A_t - A_{t-1}); \text{ for } t = 1, \ldots, m-1 \qquad (4.2.7)$$

By the use of the above relationships Z can be expressed in terms of known variables, the parameters and the decision variables. Z is maximized by setting the first partial derivatives of Z with respect to the decision variables equal to zero. The system of simultaneous equations is then solved for the decision variables.

Estimation of the parameters involves comparing the decision variables obtained from the maximization of Z with the levels of the decision variables obtained from the data and adjusting the parameters so as to make the estimated decision variables as close as possible to the actuals. The estimation of the model is discussed fully in the next chapter. Once the model has been estimated it can be used to project future stock numbers and the level of inputs and output by using the estimated decision variables.

CHAPTER FIVE

ESTIMATION, RESULTS, EVALUATION AND PROJECTIONS

In this chapter the model, described in Chapter Four, is used to project future output and input levels on the average milk supply dairy farm in the Taranaki/Western Uplands region.

In the first section of this chapter, the procedures followed in estimating the values of the parameters are described and the resulting estimates are listed. In the second section one of the sets of parameters is selected to evaluate the model and to test the responses of variables within the model to price changes. The model's ability to make one year projections is also evaluated. The third section discusses the projections outside the period over which the model is estimated, and in the final section the results obtained in the chapter are summarised.

5.1 Estimation of the Parameters

The model contains 24 parameters that need to be estimated to fit the model to the historic decisions made by the dairy farmer. The majority of these parameters need to be estimated simultaneously to take account of any interactions between decision variables and parameters. Given that there are eleven years of data and that the model is non-linear, there is no known method with known properties of simultaneously estimating all the parameters. The procedures used here will give estimates of the parameters but the properties of the method and the errors associated with each estimated parameter are unknown.

The model estimates three decision variables for each year. The estimates of the decision variables can be compared with the actual

decisions made by the farmer. The aim is to estimate as closely as
possible the actual decision variables which is achieved
by adjusting the values of the parameters in the model. However, a
change in one parameter value may reduce the difference between the
actual and estimate for one decision variable but may cause the
difference for another decision variable to increase. Therefore, a
criteria is required to indicate whether a new parameter value improves
the overall fit of the model. In other words, the differences
between actuals and estimates have to be combined in such a way that
represents the relative importance of each decision variable.

One method which allows the point estimation of the parameters of
a non-linear function is outlined by Box and Draper $\boxed{6}$. The method
minimizes the determinant (F) of a matrix (H), of the differences
between actuals and estimates of the decision variables. The
diagonal elements of H are the sums of squares of differences for each
decision variable and the off diagonal elements are the sums of cross
products of the differences for each decision variable from each other
decision variable. That is:

$$H = \begin{bmatrix} \sum_{i=1}^{n} (DV_1 - \hat{DV}_1)^2, & \sum_{i=1}^{n} (DV_1 - \hat{DV}_1)(DV_2 - \hat{DV}_2), & \dots \\[2em] \sum_{i=1}^{n} (DV_2 - \hat{DV}_2)(DV_1 - \hat{DV}_1), & \sum_{i=1}^{n} (DV_2 - \hat{DV}_2)^2, & \dots \\[2em] \vdots & \vdots & \ddots \end{bmatrix}$$

and $F = |H|$;

where DV = decision variables,

     n = the number of years of data

     $\hat{DV}$ = the estimate of the decision variables, and

     the subscripts refer to each decision variable.

As the estimates of the decision variables approach the actuals,
F approaches zero. Thus estimation of the parameters involves
adjusting the parameters so as to reduce F. In estimating the

parameters, a variety of procedures are used.

The values of several of the parameters within the model are independent of the decision process and can be assumed to be determined outside the model. By using this assumption, the milkfat production parameters and the survival rates are estimated directly from the data.

Several variations of equation $(4.2.1)$ (the milkfat production equation) are estimated using ordinary least squares regression. The details are given in Appendix B. The parameter values used in the model are those for equation B2 given in Table B.1, Appendix B. The average influence of the weather over the period of the study is included in the constant term (e_1). The values of the e's actually used in the model are included in Table 5.1.

The survival rates have to be estimated before the other parameters in order to derive the actual number of cows culled. The survival rate of cows in milk (γ_1) is estimated using data on the average wastage rate of cows in milk for New Zealand, published by the New Zealand Dairy Board $[44]$. The assumption is made that the Taranaki/ Western Uplands region has the same wastage rate as the average New Zealand rate. The rate of survival of heifers (γ_2) depends mostly on the proportion that conceive. Due to the lack of data on heifer conception rates, it is assumed that at each insemination two thirds of the heifers conceive,* and that those heifers that do not conceive, are reinseminated between two and three times. The percentage is then rounded. The rate of survival of female calves (γ_3) is estimated on the assumption that in most years one female calf per herd will die after January in each season. The rates used in the model are given in Table 5.1.

In order to be able to compare actuals and estimates of the decision variables, the actual decisions made over the period of the study have to be extracted from the date. The New Zealand Dairy Board collects information during its cow census survey on the number of

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* The conception rate is based on data on artificial breeding rates of return $[44]$.

calves reared as herd replacements on a regional basis $\sqrt{44}$. The proportion of these calves to the number of cows in the region is multiplied by the average herd size data given in Table A.5, Appendix A, to provide an estimate of the number of female calves reared in each year. The number of heifers being held as herd replacements is obtained using the heifer stock reconciliation (equation (4.2.6)). The number of cows culled each year is then estimated using the cow reconciliation (equation (4.2.5)), rearranged as follows:

$$C_t = \gamma_1 . CM_t + \gamma_2 . H_t - CM_{t+1}$$

$$\text{for } t = 1, \ldots, n .$$

The number of heifers held in 1963/64 is assumed to be in the same proportion to the number of cows in milk as the proportion of heifers to cows published in the official cow census data $\sqrt{51}$. The estimates of the numbers of culls, heifers and female calves reared are presented in Table C.1, Appendix C.

The remaining parameters are estimated using the full model. In order to run the full model the farm area in 1962/63 and the farmer's planning horizon need to be determined. The average farm area in 1962/63 is assumed to lie on the effective farm area trend line. The average dairy farmer's planning horizon is assumed to be 5 years. Five years allows time for female calves reared in the year the plan is made, to be fully producing at the end of the planning horizon.

The price expectation constants(g's) are estimated by testing a limited number in the model and selecting those that give the lowest F. This procedure requires that the other parameters are set at what appears to be reasonable values. The estimated values of the g's, are presented in Table 5.1.

The remaining parameters are estimated simultaneously using an efficient procedure developed by Powell $\sqrt{61}$. This is a steepest descent procedure that adjusts n parameters, one at a time, to minimize a statistic (in this case F) without calculating first derivatives. The procedure is available as a computer subroutine and does not require modification for this study.

Table 5.1:   Parameter Values Estimated Outside the Model

Equation no.	Parameter	Value
Milkfat Production		
4.2.1	e_1	84.479
"	e_2	-25,427
"	e_3	4.7118
"	e_4	-0.00039
Survival Rates		
4.2.5	γ_1	0.947
"	γ_2	0.900
4.2.6	γ_3	0.960
Price Expectations		
4.3.7	g milkfat	0.5
"	g culls	0.0
"	g surplus calves	0.0
"	g cow inputs	1.0

Given that the model is non-linear, several local minima are likely to exist.   The possibility of local minima is allowed for by beginning estimation from several starting parameter values.   In one of the estimation runs (minimum 3), the discount rates are estimated as a constant interest rate.   In other runs the discount rates are estimated directly.   The estimates of parameter values and level of F for three minima are given in Table 5.2.

5.2   Discussion of the Results and Evaluation of the Model

5.2.1   The parameter values

The parameter values, estimated outside the model, are presented in Table 5.1.   The milkfat production parameters are discussed in Appendix B.

Table 5.2:   Parameters Estimated Simultaneously

Equation no.	Parameter	Minimum 1	Minimum 2	Minimum 3
Milking Cost				
4.2.3	a_1	355.9856	498.4159	1808.0509
"	a_2	-0.9469	-1.6575	-4.9140
Heifer Cost				
4.2.4	b	-30.1069	1.5492	-54.0193
Inter Year Function				
4.3.3	δ_1	-1.1183	-1.7389	-1.0347
"	δ_2	8.9981	6.6014	42.4035
4.3.1	α_1	1.0340	0.8677	1.0236
"	α_2	0.0363	0.0101	-0.0105
4.3.5	Q_1	0.4571	0.5025	0.3356
"	Q_2	155.9810	148.6062	619.9479
Discount Factors				
4.3.6	d_2	1.4979	0.9615	0.9642
"	d_3	.0091	0.4736	0.9296
"	d_4	-0.4513	0.4245	0.8963
"	d_5	2.4718	3.1456	23.2624
	F	$.3915 \times 10^9$	$.2133 \times 10^{10}$	$.4578 \times 10^{10}$

The price expectation constants tend to reflect the relative
stability of the different price series.   The price expectation model
for the cull cow and surplus calf prices is of the cobweb type where
the current price is projected into future years.   The milkfat price
is relatively more stable and the expected milkfat advance is the current
price plus half the change in the advance between the previous and the
current season.   The cow input price expectation parameter value of
1.0 reflects the tendency of input prices to increase steadily.

Simultaneous estimation of the parameters was begun from various
parameter values.   Three sets of estimates of parameters are given in

Table 5.2. Most of the parameter values have magnitudes and signs consistent with those assumed in the building of the model. However, some of the parameters are inconsistent. In particular, the cost parameter a_1 in all sets is positive and large and the cost parameter b is positive for minimum 2. These cost parameters were assumed to be negative. The inter-year decision parameter δ_1 is negative and of such magnitude that as the number of female calves reared in the first year increases, the number reared in the second year will decline markedly. The estimated Q_2, in all sets is large and gives an undue influence of the envisaged changes in cow numbers on the envisaged level of cow inputs.

The discount parameters for Minimum 1 indicate that the expected income in year two is preferred to income in other years. The negative value for d_4 indicates that the expected income in year four detracts from the farmer's utility. In Minimum 2, future expected income is discounted at an increasing rate for each year. Minimum 3 has an estimated constant discount rate of 3.716 percent.

5.2.2 Evaluation of the model

Various criteria could be used to select the set of parameters to evaluate the model and to make projections. Since the criteria that is used to select particular parameter values is the minimization of F, this criteria is used to justify the selection of Minimum 1 parameter values in further applications of the model. The model is now evaluated. Projections are discussed in the next section.

Three methods are used to evaluate the model. The first procedure compares the actuals and estimates of the decision variables for the period over which the model is estimated. The series of actuals and estimates of the decision variables are shown in Figures 5.1 and 5.2. As can be seen in Figure 5.1, the estimates of the number of cows culled each year is reasonably close to the actuals and all turning points are correctly predicted. The correlation between the two series is 0.934. This correlation is reduced by the serious under-estimation of cows culled in 1965/66. The estimates of the

female calves reared are slightly less accurate and appear to predict turning points one year after they occur. No obvious reason for this occurrence exists and no attempt is made here to explain it. The correlation between the two series is 0.846. The model estimates cow input levels of the correct magnitude but fails to predict several turning points. Part of this poorer estimation for cow inputs may be due to the series of actuals. The series is constructed by adding together the amounts spent on a number of inputs that influence per cow performance. The separation of inputs between those that affect cow performance and those that are affected by cow numbers or output levels, is very imprecise. The series is then deflated by an index of the prices of all inputs used on the dairy farm weighted by the proportions spent on each input. The correlation between the cow input estimates and actuals is 0.814.

The second type of evaluation tests the models ability to project cow numbers within the period of estimation. Two types of projections are made. In the first, the model is used to project cow numbers one year ahead using the previous year's actual number of cows in milk, heifer numbers and prices, but using the estimated number of cows culled. This yields reasonable results as indicated in Figure 5.3 by the dashed line. The over estimation of cow numbers in 1966/67 is due to the under-estimation of culls in 1965/66. The correlation between the actuals and estimates is 0.971. The second projection method tests whether errors in the model compound as the model projects more than one year ahead. Actual stock numbers in 1963/64 are used to begin the projections of cow numbers. Estimates of decision variables and projections of stock numbers are used from then to 1973/74. In all the projections, actual and expected prices and farm area are used. The results are indicated by the dotted line in Figure 5.3. The effect of an under-estimation of culls in 1965/66 raises the series above the actuals, but the errors do not appear to compound. The correlation between the actuals and estimates is 0.980, which is higher than for the other method because the previously discussed method under-estimated the number of cows culled in 1966/67 (see Figure 5.1).

Finally, the milkfat production for each year is estimated using the estimates of cow input levels and the projections of cow
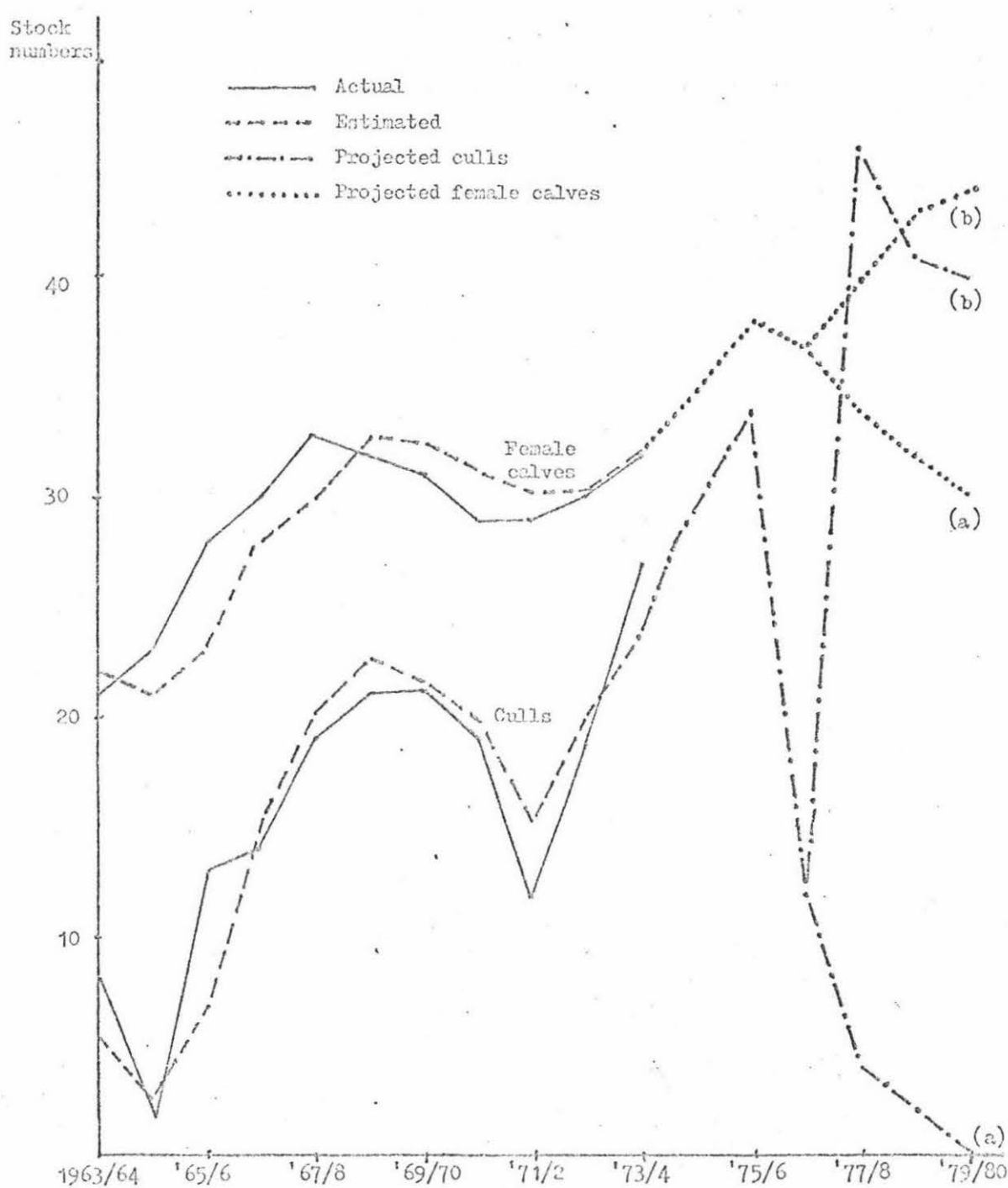
NOTE: (a) Projections using all prices increasing by 10 percent per year.
(b) The milkfat advance falls by 5 percent per year and all other prices increase by 10 percent per year.

SOURCE: Table C.1 and Table C.2, Appendix C.

Figure 5.1: Actual, Estimated and Projected Stock Numbers

NOTE: (a) Projections using all prices increasing by 10 percent per year.
     (b) The milkfat advance falls by 5 percent per year and all other prices increase by 10 percent per year.
SOURCE: Table A.5, Appendix A and Table C.2, Appendix C.
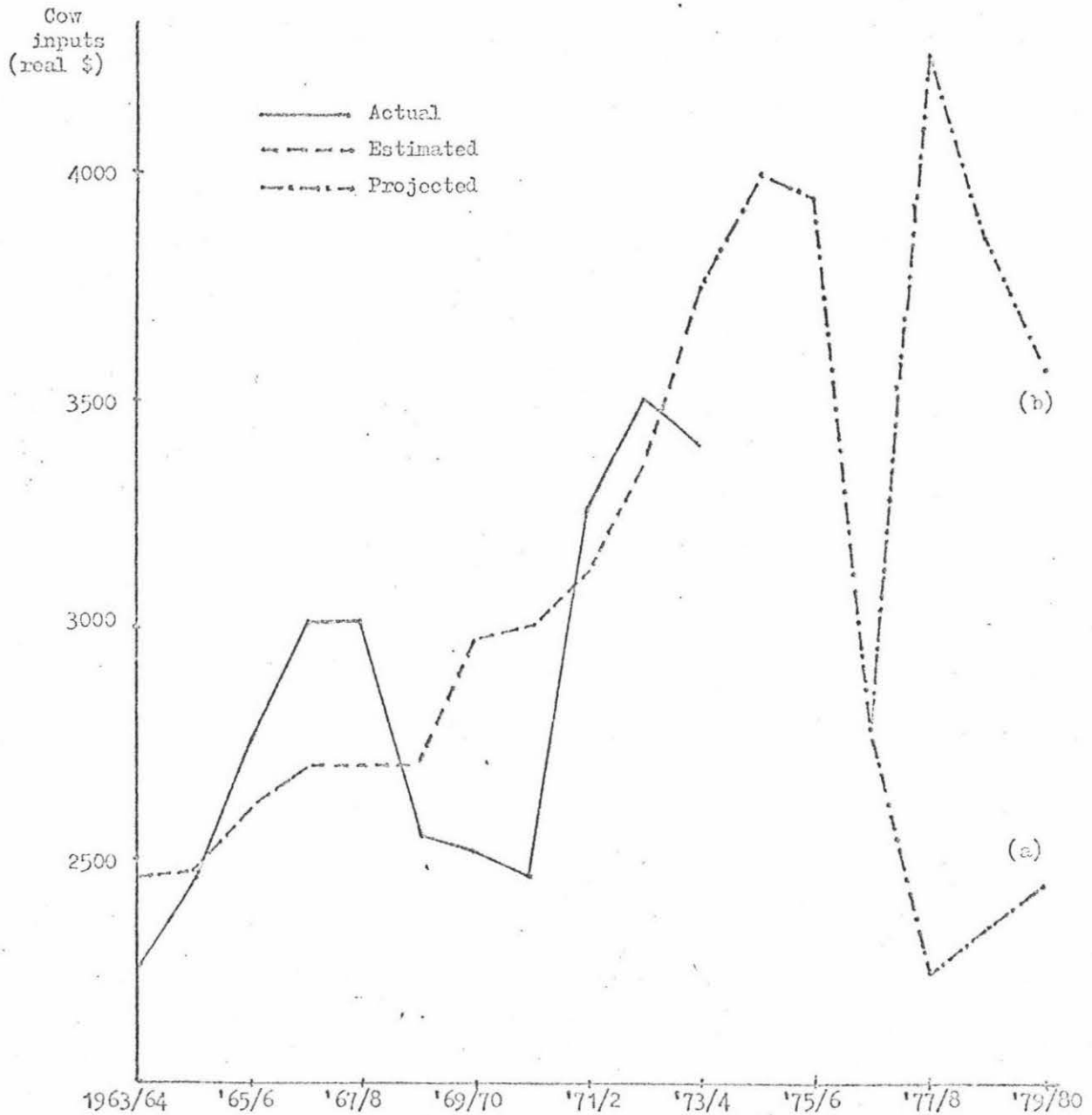
Figure 5.2: Actual, Estimated and Projected Cow Inputs

Cow
numbers
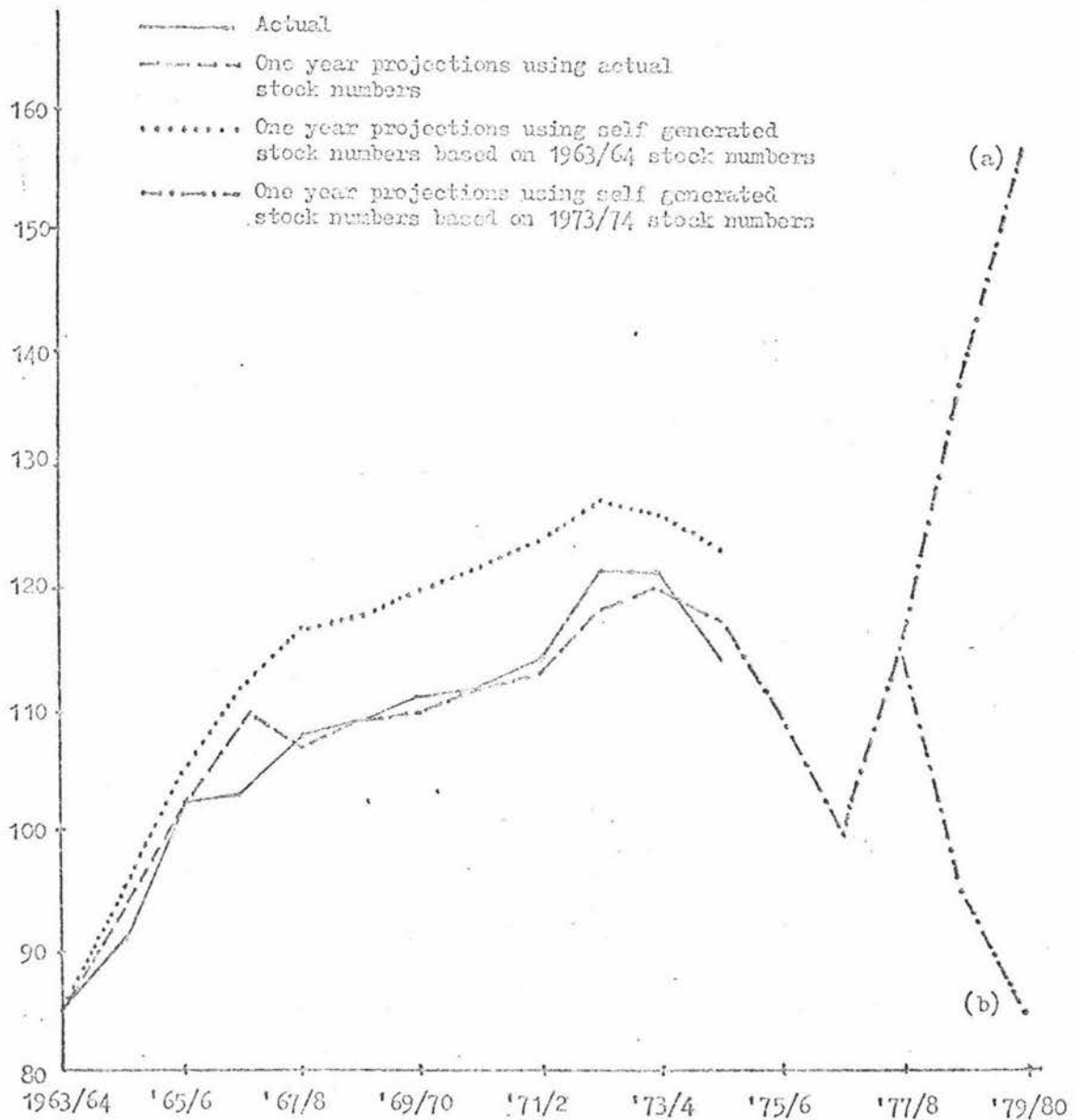
――――― Actual

―・―・― One year projections using actual
stock numbers

・・・・・・・ One year projections using self generated
stock numbers based on 1963/64 stock numbers

―・――・― One year projections using self generated
stock numbers based on 1973/74 stock numbers

SOURCE: Table C.2, Appendix C.

NOTE: (a) Projections using all prices increasing by 10 percent per year.
       (b) The milkfat advance falls by 5 percent per year and all other
            prices increase by 10 percent per year.

Figure 5.3:   Actual and Projected Cows in Milk

numbers.   The projections of cow numbers is the series derived from
actual stock numbers in the previous year.   The actuals and estimates
of milkfat production are shown in Figure 5.4.   The poor estimation of
cow inputs reduces the accuracy of the estimates of milkfat production.
However, the majority of the turning points are correctly predicted but
the magnitudes of the changes between years are not so well estimated.
The correlation between the two series is 0.868 which indicates a
reasonable degree of accuracy.

For the period of the study, 1963/64 to 1973/74, the model
estimates the number of cows culled with a reasonable degree of accuracy.
Because of this accuracy, projections of cow numbers are reasonably
accurate.   The estimation of cow input levels has the lowest correlation
between series of actuals and estimates and this affects the accuracy
of estimates of milkfat production, but the level of error between
actuals and estimates of milkfat production are less than those for cow
inputs.

5.2.3 The responses to price changes

The basis of the model is that as prices change the dairy farmer
adjusts his current production and he plans to adjust his future
production levels.   In order to quantify the extent of the farmer's
reaction to price changes the model is used to estimate the decision
variables, milkfat output and to project cow numbers using the average
prices and stock numbers for the period of estimation.   Cow numbers
are projected by the simpler of the two methods described in Chapter 4.
The projections using this method give an indication of the direction
in which the farmer is moving.   Because of the unsatisfactory nature
of some of the inter-year decision variables, the magnitude of the long
run changes in cow numbers needs to be treated with some caution.
Each price is increased by 10 percent while the other prices remain at
their average level.   The responses are recorded in Table C.3,
Appendix C.   The percentage changes in response to a 10 percent change
in each price are given in Table 5.3.   As can be seen, there is very
little response to changes in the prices of culls and surplus calves.
However, as the milkfat advance increases, the number of cows culled

SOURCE: Table C.2, Appendix C.

NOTE: (a) Projections using all prices increasing by 10 percent per year.
         (b) The milkfat advance falls by 5 percent per year and all other
              prices increase by 10 percent per year.

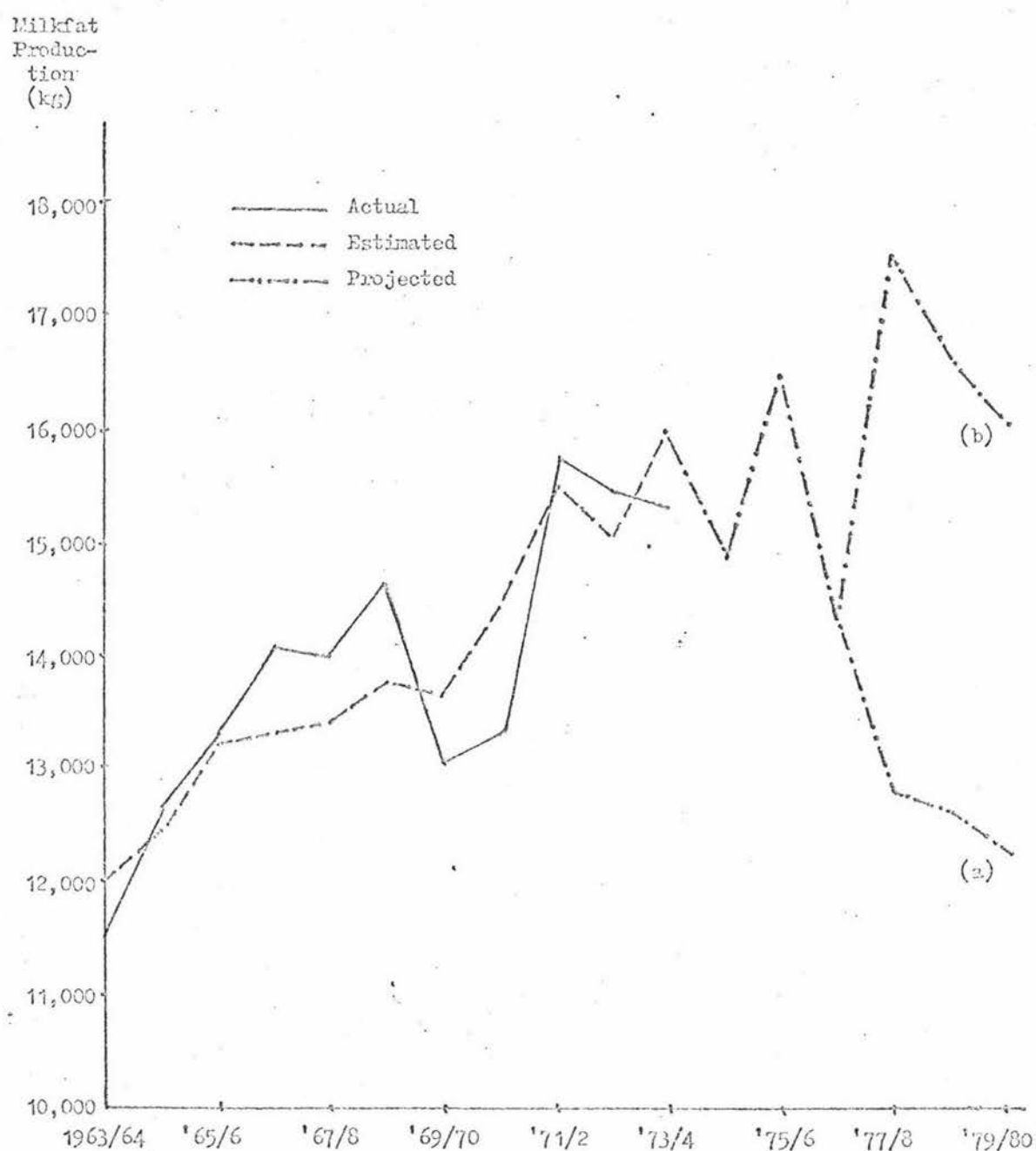Figure 5.4:   Actual, Estimated and Projected Milkfat Production per Farm

declines, the number of female calves reared increases, cow inputs increase and the herd size expands. The long run response of cow numbers to the changes in the milkfat advance is greater than the short run response. The response to changes in the price of inputs is larger than that for the milkfat advance. In this case, the number of culls increases, the number of female calves reared declines, cow inputs increase and the herd size contracts. Once again, in the long run, the response is greater than the short run.

Table 5.3: The Percentage Change in an Estimated Variable due to a 10 Percent Increase in the Average Price

	10 percent increase in the price of			
Variables	Milkfat advance	Cull cows	Surplus calves	Cow inputs
Culls in year 1	-3.8	+0.6	-0.6	+5.8
Female calves reared in year 1	+1.4	0.0	0.0	-0.3
Cow inputs in year 1	+5.6	+0.3	0.0	+6.3
Milkfat production in year 1	+2.8	+0.2	0.0	+3.2
Cows in year 2	+0.5	-0.2	0.0	-0.9
Cows in year 3	+1.2	-0.3	0.0	-1.8
Cows in year 4	+6.5	-3.2	+0.3	-11.8
Cows in year 5	+8.8	-1.5	+0.3	-11.1

SOURCE: Table C.3, Appendix C.
NOTE: The percentage changes are calculated using the unrounded changes in the variables

The only response not predicted by the theory of investment, is the increase in cow inputs in the current year, as the price of inputs rise. From the theory of investment, an increase in the costs of holding cows would decrease the capital value of all cows and hence the number culled would increase. This says very little about the expected change in inputs. If the level of inputs remains constant on a fixed area of land as the number of cows declines, the inputs per cow would increase, milk production per cow would increase, but total milkfat production is expected to decline. Thus the reason that

inputs increase is to increase total milkfat production. However, increased cow input prices result in a decline in cow numbers which would reduce total milkfat production in the long term.

5.3 Projections

In the previous chapter two methods of making projections were outlined. In this section one of the methods is used to make projections up to 1979/80. The method uses the stock numbers projected from the previous year and projects the decision variables for each year. The decision variables are projected using projected prices and projected farm area. The projected levels of prices and farm area have to be obtained from outside the model.

In projecting the decision variables up to 1976/77, actual prices, obtained from the same sources as used in estimating the parameters, are inserted into the model. Prices for the 1976/77 season are projected at the level they were at the middle of the season. For 1976/77, input prices are assumed to increase by 15 percent. From 1976/77 to 1979/80, two sets of price projections are used. The first takes all prices as increasing by 10 percent per year and the second takes the milkfat advance as decreasing by 5 percent per year while all other prices increase by 10 percent per year. The projected prices are included in Table A.2, Appendix A.

In all the projections farm area is held constant at 61 hectares. In projecting the decision variables and cow numbers, rainfall is the average level over the period of estimation of the parameter values.

The projected number of cows culled and female calves retained are included in Figure 5.1. The projected level of cow inputs are included in Figure 5.2 and the projected number of cows are included in Figure 5.3.

In projecting milkfat production, the projected stock numbers are used, farm area is held constant at 61 hectares and input costs are those projected for each year. For the projections of milkfat production up to and including 1975/76, actual rainfall figures are

used. From 1976/77 to 1979/80 milkfat production is projected using
the average rainfall over the period of estimation of the parameter
values. The projections of milkfat production are included in
Figure 5.4.

The number of cows culled, the number of female calves retained
and the level of cow inputs are all projected to decline in 1976/77
as compared with 1975/76. The number of cows in milk is expected to
decline in 1976/77, but because of the projected decline in the number
of cows culled that year, the number of cows in milk is projected to
increase in 1977/78. In 1976/77 milkfat production is projected to
decline due to a decline in cow inputs and in cow numbers.

From 1976/77 to 1979/80, if all prices increase by 10 percent per
year, the average farmer is projected to rapidly expand his herd size
by decreasing the number of cows culled. At the same time he is
projected to decrease the level of cow inputs up to 1977/78 and then
to increase them. As a result of the projected increase in stocking
rate and the projected changes in cow inputs, milkfat production is
projected to decline up to 1979/80.

Over the same period, if the milkfat advance decreases by 5 per-
cent per year and all other prices increase by 10 percent per year, the
average farmer is projected to decrease his herd size by increasing
the number of cows culled. He is also projected to increase the level
of cow inputs up to 1977/78 and then to decrease the level of cow
inputs. As a result of these changes milkfat production is projected
to increase up to 1977/78 and then to decline.

All these projections are conditional on the prices, farm area
and rainfall used in deriving them. As the number of years for which
projections are made increases, the projections become conditional on
these prior projections eventuating and any errors will be carried
into the next year's projections. The projections of cow numbers are
in addition, conditional on the projections of the decision variables
in the previous year. The milkfat production projections are, in
turn, conditional on all the previous projections and will contain
errors due to the projections of these other variables. Further,
the projections for the period from 1976/77 to 1979/80 use prices from

well outside the range of prices used in estimating the parameters
in the model and therefore must be treated with some caution.

5.4 Summary of Results

In this section the results of the estimation and evaluation of
the model and the projections are summarised.   Estimation of the
parameters in the model began from several starting parameter values.
All sets of parameter estimates contain parameters with unsatisfactory
signs and magnitudes.   However, parameter values selected to evaluate
the model, give reasonable estimates of the decision variables.   The
model accurately predicts all the turning points in the actual cull
cow series but fails to predict several of the turning points in the
other decision variable series.   The correlations between actuals and
estimates of the decision variables are:

     (a)   cull cows   0.934,

     (b)   female calves   0.846,

     (c)   and cow inputs   0.814.

The model projects cow numbers over the period of estimation with
a reasonable degree of accuracy when projecting from the actual cow
numbers.   When projecting using previously projected cow numbers,
errors are carried forward, but do not appear to multiply.   The estimates
of milkfat production do not change between years by the same magnitude
as the actuals but most of the turning points are correctly predicted.
The correlations between actuals and estimates are:

     (a)   cow numbers projected using actual stock numbers   0.971,

     (b)   cow numbers projected using projected stock numbers 0.980,

     (c)   and milkfat production   0.868.

The effects on the model of changes in prices indicate   that
changes in the prices of inputs have a greater influence than changes
in the milkfat advance.   The changes predicted by the model are
consistent with those predicted by the theory of investment.

Projections of decision variables, cow numbers and milkfat

production are made beyond the period over which the model is estimated.
It is pointed out that the projections are conditional on the variables
used and the previous projections.   The projections indicate that,
compared with 1975/76:

(a) the number of cows culled in 1976/77 is expected to
     decline;

(b) the number of female calves reared as herd replacements
     in 1976/77 is expected to decline;

(c) the level of cow inputs is expected to decline in
     1976/77;

(d) cow numbers are expected to decline in 1976/77 but
     to increase in 1977/78;

(e) total milkfat production on the average farm is
     expected to decline in 1976/77.

The projections from 1976/77 to 1979/80 indicate that if all
prices increase by 10 percent per year, cow numbers would increase but
both cow inputs and milkfat production would decrease.   If the
milkfat advance decreases by 5 percent per year and all other prices
increase by 10 percent per year, cow numbers are projected to decline
but cow inputs and milkfat production are projected to initially
increase and then to decline.

CHAPTER SIX

CONCLUSIONS

This study considered an average factory milk supply dairy farm in the Taranaki/Western Uplands region and the changes that have occurred on that farm from 1963/64 to 1973/74. The aim of the study was to build a model that could be used to project future dairy farm output, stock numbers and the level of inputs on a regional basis. A model of the dairy farm production system and the farmer decision process was built and the model's ability to predict the farmer's decisions, and farm output were analysed. The results of the study appear promising.

The technique used in this study requires a large amount of information. Much of this information is not currently available. This lack of information has been overcome by making assumptions concerning the forms of the production relationships and the farmer's behaviour. For these reasons this study must be considered as exploratory.

6.1 The Results and Policy Implications

The aim of this study was to build a model that could be used to project dairy production responses to changing prices. In building the model, the relationships between variables were given specific mathematical forms. The parameters inserted were unknown and had to be estimated. The estimation of the parameters involved adjusting the parameter values until the actual and estimated decision variables were as close as possible.

Some of the estimated parameter values appear unsatisfactory. In particular some of the parameters that determine the envisaged levels of future variables and one of the discount rates are of the wrong sign. One of these parameters is also of such magnitude that if the envisaged number of cows increases,

the number of female calves reared markedly declines. The result is
that the model does not indicate a feasible path to the 'optimum' plan
at the end of five years.

The cost parameters also appear to be unsatisfactory. One of the
milking cost parameters is of the wrong sign and magnitude which may be
due to not taking technological changes into account in the model. It
was assumed in the model that the technological changes that had occurred had
not influenced the production relationships. However, during the period of
the study there has been a change to herring-bone milking sheds
which may have altered the milking cost parameters.

In spite of these limitations, the model estimates the historical
decisions made by the average dairy farmer with a reasonable degree of
accuracy. It is considered that the model describes the changes on the
average farm with sufficient accuracy for the model to be of use in
making projections for a limited period outside the period for which
data is available.

The model, insofar as it describes the decision process of the
average farmer, suggests that the farmer has responded more to changes
in input prices than output prices over the period of study. Further,
the model suggests that changes in cull cow prices have very little
impact on the production plans and changes in surplus calf prices have
even less impact.

This analysis implies that if New Zealand policy makers wish to
increase milk production, they should pay close attention to the price
of inputs such as fertilizer and other inputs that are thought to
influence per cow production. In the short run (in the current season),
an increase in the price of some inputs is likely to increase milk
production. In the long term, increased prices of these inputs are
likely to decrease dairy farm output since the number of cows in milk
would decline. Thus, as a long term policy, close attention to the
prices of inputs rather than outputs would have a greater impact in
increasing production. Policy measures that influence the prices of
cull cows and surplus calves ceteres paribus, are not likely to have a
great impact on production. However, a dairy company in the Taranaki
region wishing to increase milk production in the short and long run,

is likely to have a reasonable degree of success by increasing the milkfat advance price.

The projections outside the period for which data was available for estimating the parameters, indicate that as compared with 1975/76, dairy farmers would decrease herd size and milk output in 1976/77. The projected decline in milk production is due to a projected decline in inputs that are considered to influence per cow milk production. Since cow numbers are projected to decline, total milkfat production is projected to decline. It is also projected that a smaller number of cows would be culled in 1976/77 in the region (as compared with 1975/76) in order to increase herd size in 1977/78.

The projections from 1976/77 to 1979/80 indicate that, if all prices increase by 10 percent per year, cow numbers would increase but both cow inputs and milkfat production would decrease. If the milkfat advance decreases by 5 percent per year and all other prices increase by 10 percent per year, cow numbers are projected to decline but cow inputs and milkfat production are projected to initially increase and then to decrease.

The projections from 1976/77 to 1979/80 are made using data projected from three to six years outside the period for which data was available for estimation of the parameters. The projections are also made with price projections from 1976/77 to 1979/80. Hence, these projections are conditional on these prior projections and include the errors in these other projections.

6.2   The Approach to Supply Analysis and its Limitations

The average dairy farmer was assumed to make a plan each year that envisaged changing stock numbers over the next five years so that at the end of five years the dairy farmer milked an 'optimum' number of cows. The 'optimum' was where the discounted expected income stream was maximised over time, given the farmer's discount rate. The expected future income depended on the farmer's expectation of future prices and the expected production levels. The expected production levels depended on the envisaged number of stock and the level of

certain inputs. In order to alter production in the direction of the 'optimum' plan, the dairy farmer adjusted current stock numbers and inputs.

In practise the dairy farmer never achieves the 'optimum' due to factors such as price changes influencing price expectations. Thus, the variables after the first year cannot be observed. Hence, these envisaged variables were expressed in terms of variables in the first year of the plan, which were observable. Envisaged stock numbers, envisaged decision variables and expected future prices were all assumed to depend on specific mathematical expressions concerning the previous year's variables. These mathematical expressions allowed the farmer's assumed objective function (the discounted expected future income stream) to be expressed in terms of observable variables.

The approach adopted for this study required a great deal of information concerning the decision process of the average farmer and production interrelationships of the farm. Much of this information is not currently available in New Zealand and thus, many assumptions were made in building the model. These assumptions will have contributed to the unsatisfactory nature of some estimated parameter values discussed in the previous section. In the approach used these errors can only be avoided by a more complete knowledge of the farmer's decision process and would have decreased the ability to model the process in a manner so that the model can be solved for the important decision variables.

Information concerning the objective function of farmers, how farmers form their price expectations and the relationships between current and envisaged variables would have greatly reduced the errors in the decision process. A more mathematically complicated objective function would have reduced the possibility of obtaining an analytical solution and increased the costs of estimation. A similar result would have occurred with more complicated price expectation functions, but more information on how farmers form their price expectations may have reduced the number of parameters to be estimated within the model. As well, it may also have increased the reliability of the price expectation parameter estimates.

The ability to solve the model analytically depended on the assumption of quadratic production and cost relationships which if relaxed would have introduced more variables to be estimated and increased the complexities of the model. Other techniques would need to be used to solve the model and estimate the parameters.

A major limitation in this model is the assumptions concerning effective farm area. A method of introducing farm area as a decision variable would have been more realistic. This addition would also have increased the complexities in the model and would have made it difficult to obtain an analytical solution.

A further limitation of the approach has arisen in the course of the study through the inability to separate the input items in the data more precisely. This problem and the problem concerning the index of input prices are more concerned with the data and could be overcome with a more careful study of the inputs and prices.

The limitations discussed above could partly be overcome with more research into these areas. The simplicities of this study, however, could well disappear.

Despite these limitations, the results of this study suggest that the approach has merit and could be used to provide a method of projecting dairy cow numbers, dairy production and input levels in New Zealand. The study has also identified areas of dairy supply response that would benefit from further work. Such investigation could be of benefit to supply analysts not inclined to formal model building as well as allowing a more complete supply model to be considered.

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APPENDIX A

THE DATA

TABLE A.1: TARANAKI/WESTERN UPLANDS REGION

	NO. OF FACTORIES a)	NO. OF SUPPLIERS a)	NO. OF COWS IN MILK b) (000)
1963/64	37	3906	297
1964/65	36	3794	303
1965/66	32	3715	313
1966/67	28	3665	311
1967/68	22	3590	336
1968/69	21	3620	352
1969/70	21	3548	360
1970/71	21	3402	369
1971/72	21	3262	351
1972/73	21	3183	332
1973/74	19	3046	343
1974/75	15	2989	
Annual Average Percentage Change 1963/64 to 1973/74	-6.8	-1.9	1.3

SOURCES: a) N.Z. Dairy Board.

b) Government Statistition /51/

123.

TABLE A.2: REPRESENTATIVE PRICES
RECEIVED AND PAID BY DAIRY FACTORY
MILK SUPPLIERS IN TARANAKI

	TOTAL MILKFAT a) (c/kg)		CULL COWS b) ($/Head)	SURPLUS CALVES c) ($/Head)	INPUT PRICES d) (Index)	OUTPUT PRICE c) (Index)
1963/64	85.815		35.20	4.45	1000	1000
1964/65	95.851		35.28	4.40	1011	1101
1965/66	98.503		47.62	4.93	1037	1171
1966/67	91.146		44.10	6.30	1071	1194
1967/68	76.491		58.21	6.59	1112	1154
1968/69	72.744		62.96	8.84	1139	1147
1969/70	73.803		82.90	9.94	1197	1218
1970/71	85.849		77.60	9.52	1279	1380
1971/72	107.945		68.78	9.37	1339	1609
1972/73	111.376		97.01	14.12	1450	1781
1973/74	129.802		52.80	15.00	1688	1859
1974/75	131.959		41.60	7.25	1908	1768
1975/76	146.981		76.00	8.42	2174	
1976/77 f)	138.000		68.00	14.00	2500	
1977/78 g)	151.8 (+)	131.1 (−)	74.80	15.40	2750	
1978/79 g)	167.0 (+)	124.5 (−)	82.30	16.90	3025	
1979/80 g)	183.7 (+)	118.3 (−)	90.50	18.60	3330	

Annual Average
Percentage Change

| 1963/64 to 1973/74 | 3.9 | | 3.9 | 12.2 | 4.6 | 5.9 |

NOTES TO TABLE A.2

a) The milkfat prices are obtained from the following six companies:

    Bell Block Co-operative Dairy Ltd.
    Clifton Co-operative Dairy Co. Ltd.
    Kiwi Co-operative Dairies Ltd.
    Moa Farmers Co-operative Dairy Co. Ltd.
    Taranaki Co-operative Dairy Co. Ltd.
    The Warea Co-operative Dairy Co. Ltd.

    plus the companies from which they evolved.

b) Obtained from the Meat Exporters' Schedule of prices to producers in the last week of May.

c) Obtained from the N.Z. Dairy Board $/44/$

d) Obtained from $/44/$ and is a N.Z. weighted index of prices paid by dairy farmers where the prices of individual inputs are weighted by the proportion of expenditure on each item.

e) Obtained from $/44/$ and is a N.Z. weighted average of prices received by dairy farmers.

f) The 1976/77 prices are projections. The milkfat payout is the advance for the season. The cull cow and surplus calf prices have been projected by the Ministry of Agriculture and Fisheries $/53/$. The input price index is increased by 15 percent.

g) Two sets of projections are used for the seasons of 1977/78 to 1979/80. The milkfat advance is increased by 10 percent each year in one set (indicated by (+)) and decreased by 5 percent each year in the other (indicated by (-)). All other prices for the period are increased by 10 percent per year in both cases.

TABLE A.3: SOURCES OF TOTAL FARM INCOME ON MILK

SUPPLY FARMS

		MILKFAT INCOME	CALVES	CATTLE	PIGS	OTHER	TOTAL FARM INCOME
				($)			
1963/64	a)	7674	230	682	538	218	9342
1964/65		9406	232	506	526	224	10894
1965/66		10350	269	878	509	220	12226
1966/67		11335	349	1005	671	269	13629
1967/68		11281	409	1215	602	218	13725
1968/69		10371	553	1450	545	287	13206
1969/70		10476	654	1702	512	360	13704
1970/71		10530	594	2093	536	373	14126
1971/72		15481	592	1937	662	468	19140
1972/73		17591	859	2738	594	421	22203
1973/74		19651	920	2876	640	479	24566

SOURCE: N.Z. Dairy Board /43/

a) 1963/64 data includes cream supply farms.

TABLE A.4:   AVERAGE MILK SUPPLY FARM EXPENDITURE

	COW INPUT COSTS a)	OTHER INPUTS b)	CURRENT FARM CASH EXPENDI- TURE c)	TOTAL FARM EXPENDITURE d)
	($)			
1963/64 e)	2256	2860	5116	5810
1964/65	2492	3198	5690	6558
1965/66	2842	3579	6421	7288
1966/67	3234	4027	7261	8243
1967/68	3360	4230	7590	8656
1968/69	3189	4266	7455	8447
1969/70	3301	4334	7635	8735
1970/71	3459	4589	8046	9134
1971/72	4370	5657	10027	11506
1972/73	5089	6254	11343	13284
1973/74	5744	6813	12557	14432

SOURCE: N.Z. Dairy Board /43/

Notes: a)   Sum of animal health, contractors, feed, fertilizer and seed, general, weed and pest control and repairs and maintenance items.

b)   Sum of administration, breeding, dairy shed, elect-ricity, freight, vehicles, insurance, rates, labour, interest and rent expenditure items.

c)   Sum of a) and b)

d)   Sum of c) plus development, depreciation, taxation concessions, deferred expenditure, and income equali-sation transactions.

e)   1963/64 information includes cream supply farms.

TABLE A.5: ANNUAL INPUTS AND MILKFAT PRODUCTION
ON THE AVERAGE MILK SUPPLY FARM

	COWS IN MILK	FARM AREA a)	FARM LABOUR b)	COW INPUTS c)	MILKFAT PRODUCTION
	(No.)	(Hectares)	(Units)	($)	(kg)
1963/64 d)	85	43.7	1.61	2256	11468
1964/65	91	46.5	1.62	2456	12636
1965/66	102	50.2	1.68	2742	13286
1966/67	103	52.6	1.69	3020	14059
1967/68	108	51.4	1.61	3022	13964
1968/69	109	53.0	1.60	2800	14618
1969/70	111	53.8	1.56	2758	13032
1970/71	112	55.9	1.52	2704	13300
1971/72	114	59.0	1.68	3264	15720
1972/73	121	61.0	1.70	3510	15425
1973/74	121	61.0	1.69	3403	15281
Annual Average Percentage change	3.3	3.0	0.4	3.3	2.7

SOURCES: N.Z. Dairy Board /43/

Notes:
a) Farm area is the "effective farm area" as defined by the N.Z. Dairy Board /43/ and does not include farm run-off area. It is obtained from the sample of both cream and milk supply farms.

b) Farm labour is the total quantity of labour on both milk and cream supply farms.

c) The variable cow inputs is derived by deflating cow input costs by the index of prices paid by dairy farmers. Unfortunately an index of the prices of items in "cow input costs" weighted by their quantities used does not exist. Furthermore, the index of prices paid has the expenditure items weighted by the proportion of expenditure on each item.

d) 1963/64 data includes cream supply farms.

TABLE A.6: MILKFAT PRODUCTION PER COW AND INPUTS

	MILKFAT PRODUCTION PER COW	COWS PER HECTARE	COW INPUTS PER COW	WEATHER VARIABLE a)
1963/64	134.9	1.93	26.54	2.75
1964/65	138.9	1.94	27.09	2.86
1965/66	130.3	2.04	26.88	2.90
1966/67	136.5	1.94	29.32	2.83
1967/68	129.3	2.12	27.98	2.87
1968/69	134.1	2.06	25.69	2.94
1969/70	117.4	2.06	24.84	2.67
1970/71	118.8	2.00	24.14	2.84
1971/72	137.9	1.93	28.63	2.98
1972/73	127.5	1.98	29.01	2.65
1973/74	126.3	1.98	28.12	2.73
1974/75				2.88
1975/76				2.80

SOURCE: Table A.5 & /54/

Note: a) The weather variable is the logarithm to base 10 of the rainfall in millimeters from October to March (6 months) of each season. The total rainfall is obtained from the Manaia (98 meters above mean sea level) and the Stratford (311 meters above mean sea level) metereological stations, and is the average of the monthly rainfall readings. The period (October to March) appears visually to explain movements in milkfat production better than other periods and its logarithm is used to indicate a diminishing influence on production as rainfall increases.

TABLE A.7: A MEASURE OF PRODUCTIVITY

	REAL TOTAL FARM INCOME	REAL CURRENT FARM EXPENDITURE	INDEX OF PRODUCTIVITY
	(a)	(b)	(c)
1963/64	9342	5716	1000
1964/65	9895	6346	957
1965/66	10441	6941	920
1966/67	11415	7626	920
1967/68	11893	7696	950
1968/69	11514	7373	957
1969/70	11251	7220	957
1970/71	10236	7094	883
1971/72	11896	8407	871
1972/73	12467	8908	859
1973/74	13215	8413	963
Annual Average Percentage Change	3.3	3.9	- 0.6

SOURCE: N.Z. Dairy Board /43/

Notes: a)   Total farm expenditure is deflated by an index of prices received by dairy farmers.

b)   Farm cash expenditure plus depreciation is deflated by an index of prices paid by dairy farmers.

c)   The index is the ratio of a) divided by b).

TABLE A.8:   GROSS AND FACTOR OUTPUT

	GROSS OUTPUT	MATERIAL INPUT	FACTOR INCOME
1963/64	9342	5630	3712
1964/65	9895	5731	4164
1965/66	10441	5997	4444
1966/67	11415	6582	4833
1967/68	11893	7119	4774
1968/69	11514	6885	4629
1969/70	11251	6690	4561
1970/71	10236	6210	4026
1971/72	11896	6652	5244
1972/73	12467	6917	5550
1973/74	13215	7486	5729

Annual Percentage

Change	3.25	2.6	3.9

SOURCE: N.Z. Dairy Board /43/

Note: The methodology is discussed in Section 3.4.

APPENDIX B:

THE MILKFAT PRODUCTION RELATIONSHIP

Central to supply analysis is the development of a production function that explains output in terms of the inputs employed. In Chapter 3 it was hypothesised that milkfat production (MP) per cow moved in response to changes in cows in milk (CM), farm area (A), cow inputs (IC)[*], weather (W) and technology (T). In order to test these influences, it is hypothesised that the milkfat production relationship is of the form:

$$MP/CM = e_1 - e_2 \frac{CM}{A} + e_3 \frac{IC}{CM} - e_4 \frac{IC^2}{CM} + e_5 W + e_6 T + E,$$

where E is an error term.

Technology is included as a time trend variable with the level of technology equal to 1 in 1963/64 and thus takes account of gradual changes in technology. Weather is included as the logarithm to base 10 of the rainfall in the region over the six months from October to March of each season. The other variables are as given in Appendix A for the Taranaki/ Western Uplands region.

Three forms of the production function are estimated, using ordinary least squares regressions. The first equation (B1) excludes weather and technology variables, the second (B2) excludes the technology variable and the third (B3) includes all variables. The results are presented in Table B.1.

The accuracy of the estimated parameters is limited because with only 11 years of data the degrees of freedom of the equations are small. However, in all equations the coefficients are correct in sign on a priori grounds. The inclusion of the weather variable reduces the constant but leaves the other coefficients virtually unchanged. The inclusion of the time trend variable substantially alters all the coefficients excepting that for weather and increases the standard errors. Only the weather coefficient is

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[*] Cow inputs are cow input costs deflated by the index of prices paid by dairy farmers. Items included in cow input costs are given in the Notes to Table A.4, Appendix A.

significantly different from zero at the 5 percent level of test. The time trend coefficient, while not significantly different from zero, indicates that gradual improvements in technology have increased milkfat production per cow by 0.8 percent per year over the period of estimation.

The most satisfactory of the estimated milkfat production relationships appears to be equation B2 and thus this equation is used in the model. Equation B2 indicates, for example, that with an increase in stocking rate of one cow per hectare, milkfat production per cow would fall by more than 25.4 kilograms because inputs per cow would have declined as well. The investigation of equation B2 is best carried out graphically. The results are given in Figure B.1(a) to (d). Each graph is derived by varying only one variable in equation B2 at a time. For example, in Figure B1(a) the number of cows in milk is changed while the other variables are held constant at the average of their level from 1963/64 to 1973/74. Thus, Figure B.1(a) indicates the impact on milkfat production per cow of changes in stocking rate. The impact of the variables outside the range over which the equations were estimated is investigated in order to detirmine the limits of equation B2.

The goodness of fit of equation B2 is indicated in Figure B.2 where actual and estimated milkfat production per cow from 1963/64 to 1973/74 are shown.

<u>TABLE B.1:</u>   <u>ESTIMATED MILKFAT PRODUCTION COEFFICIENTS</u>

EQUATION	CONSTANT	STOCKING RATE	INPUT COSTS PER COW	INPUT COSTS SQUARED PER COW	WEATHER	TIME	DEGREES OF FREEDOM	R^2	F
B1	61.672	−20.249 (31.227)	5.430*** (1.687)	−0.00048** (.00019)			7	.700	5.45
B2	0.690	−25.427 (21.350)	4.712*** (1.174)	−0.00039** (.00013)	29.597** (9.826)		6	.881	11.08
B3	−82.672	−9.660 (38.289)	7.576 (5.730)	−0.00083 (0.00036)	30.347* (10.594)	1.087 (2.122)	5	.887	7.82

NOTE: Figures in parentheses are standard errors of the estimated coefficients

*** Indicates a coefficient that is significantly different from zero at the 1% level.
**   "   "   "   "   "   "   "   "   "   "   " 2.5% " .
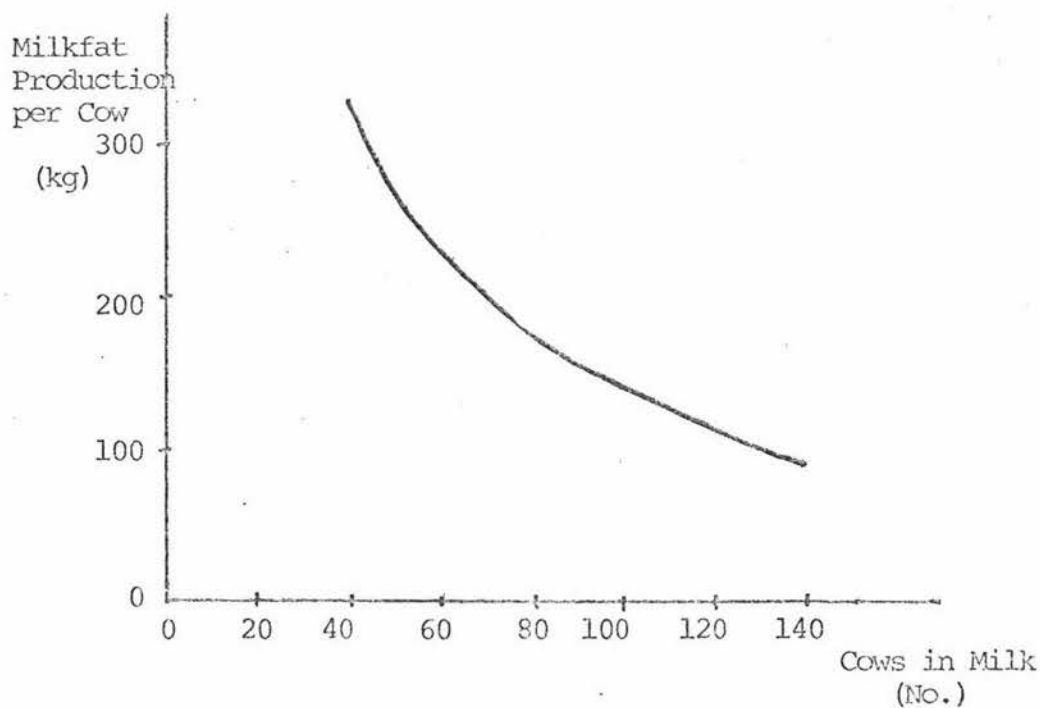*   "   "   "   "   "   "   "   "   "   "   " 5%   " .

Figure B.1(a): Milkfat Production in Response to Changes in Cow Numbers
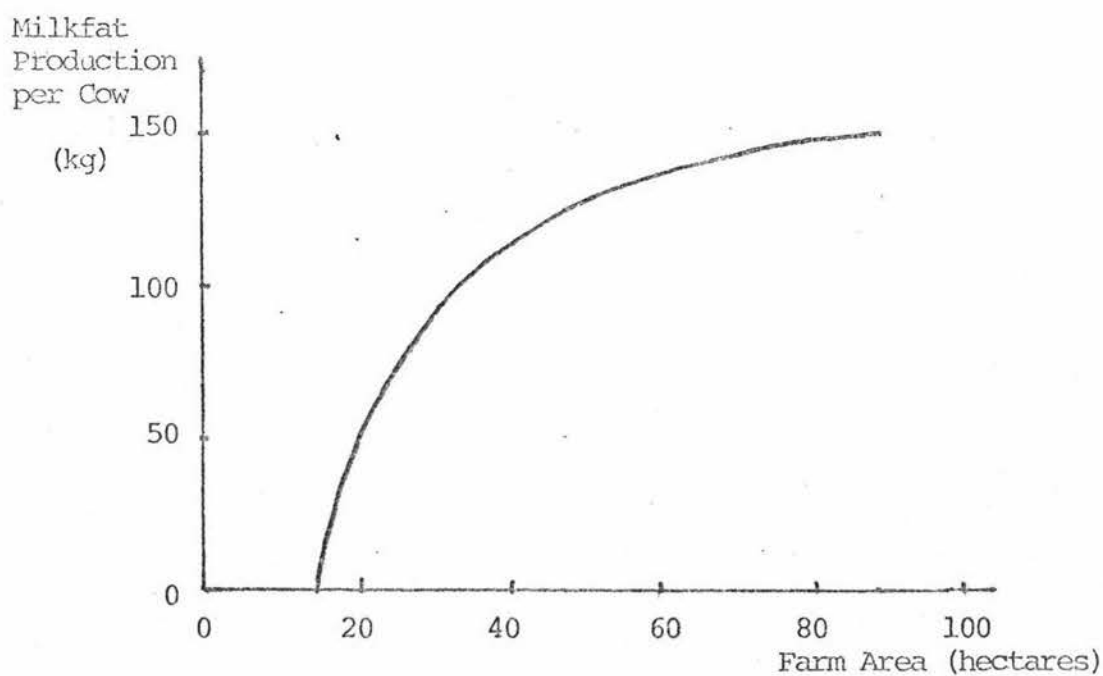

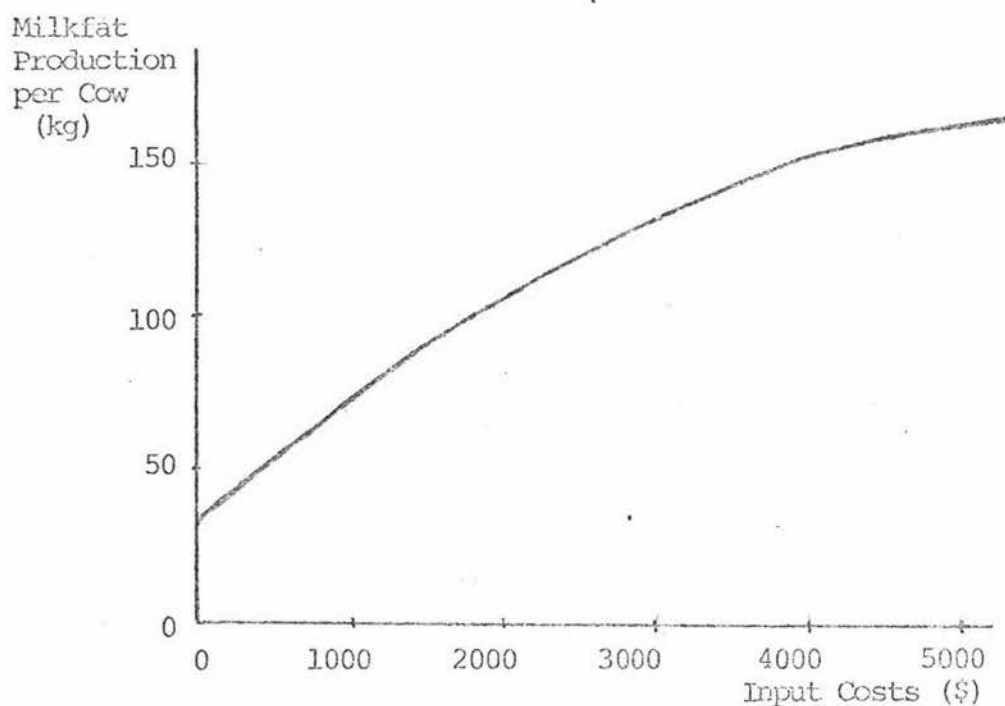Figure B.1(b): Milkfat Production in Response to Changes in Farm Area

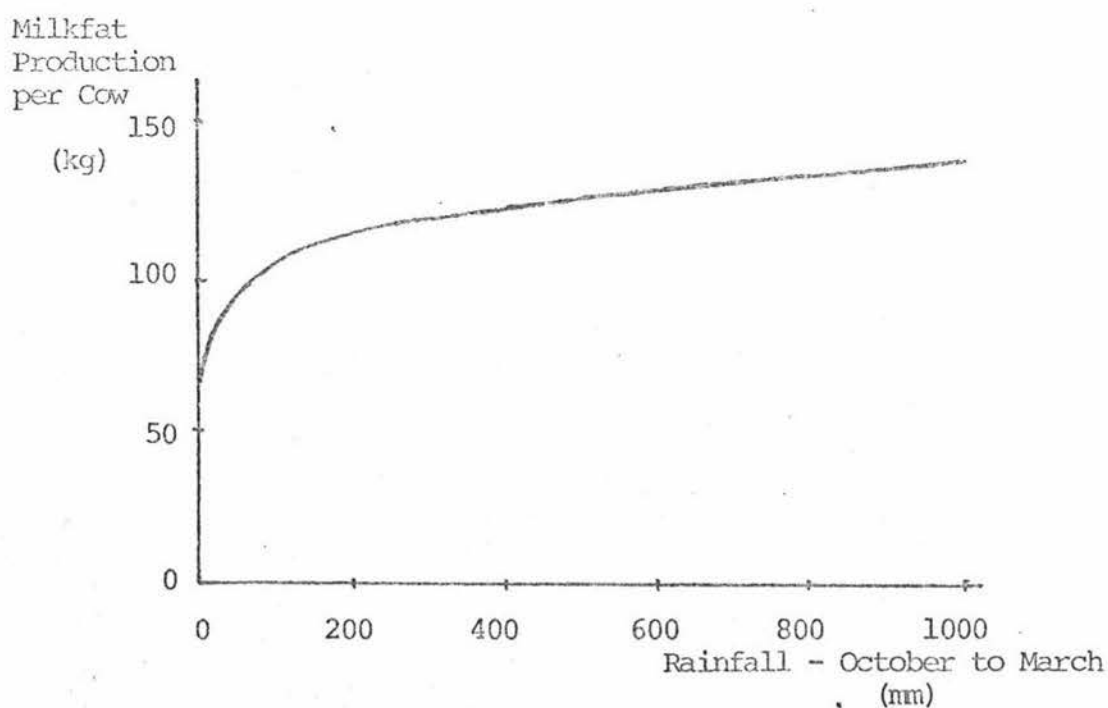Figure B.1(c): Milkfat Production in Response to Changes in Input Costs

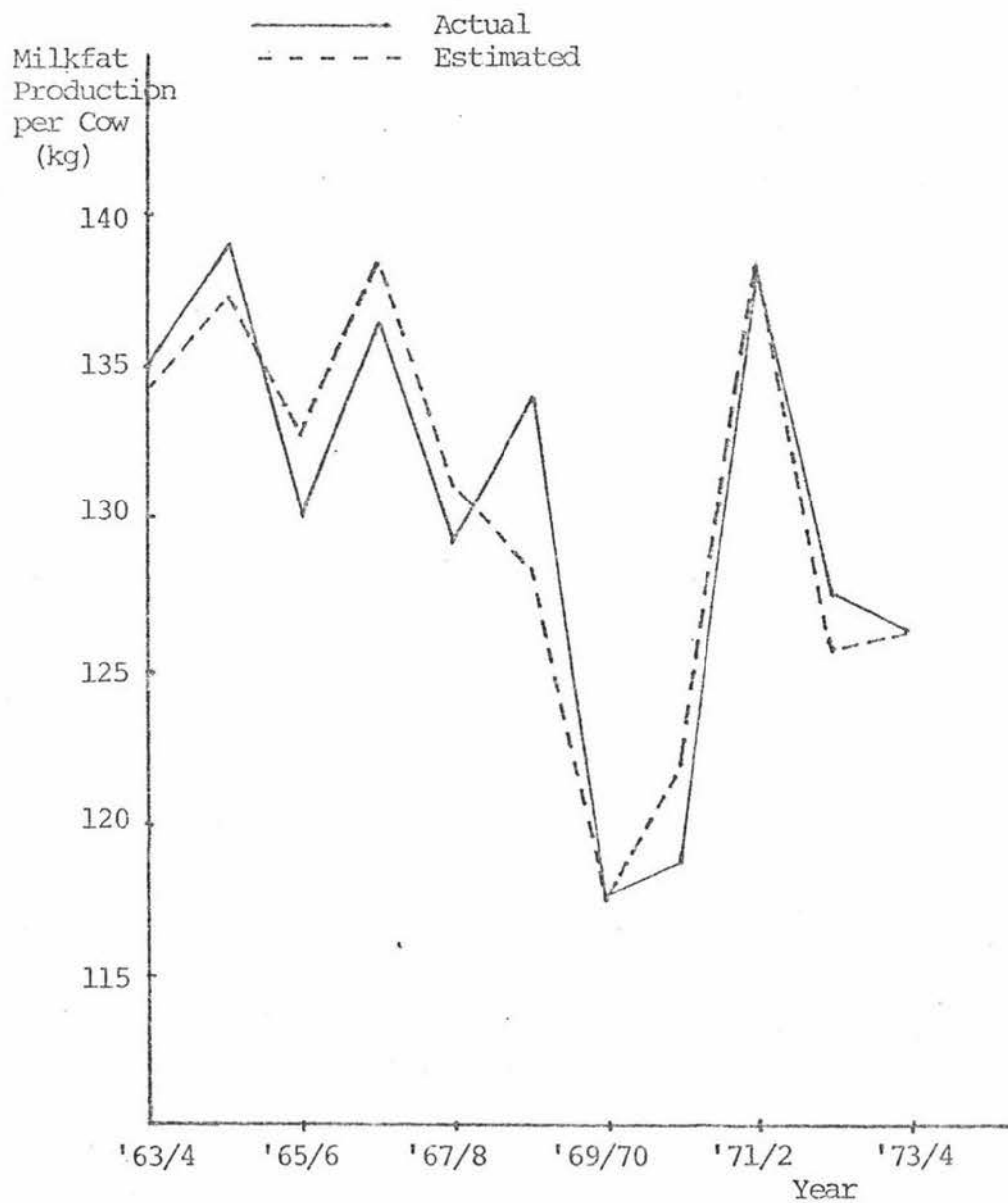Figure B.1(d): Milkfat Production in Response to Changes in Rainfall

Figure B.2: Estimated and Actual Milkfat Production per Cow

APPENDIX C:

THE RESULTS

TABLE C.1 : STOCK NUMBERS DERIVED FROM THE DATA

	Cows in Milk	Cows Culled	Heifers	Female Calves Reared
		(a)	(a)	(b)
1963/64	85	8	21	21
1964/65	91	2	20	23
1965/66	102	13	22	28
1966/67	103	14	27	30
1967/68	108	19	29	33
1968/69	109	21	32	32
1969/70	111	21	31	31
1970/71	112	19	30	29
1971/72	114	12	28	29
1972/73	121	19	28	30
1973/74	121	27	29	32
1974/75	114[c]			

Source: Table A.5 and the Stock Reconciliation Equations (4.2.5 and 4.2.6).

NOTES: (a) Estimated using the stock reconciliation.

(b) Obtained from the percentage of female calves wintered on dairy farms [44].

(c) Provisional.

TABLE C.2 : ACTUAL, ESTIMATED AND PROJECTED DECISION VARIABLES, COW NUMBERS AND MILKFAT PRODUCTION

	ESTIMATED DECISION VARIABLES [a]			COW NUMBERS			MILKFAT PRODUCTION	
	CULLS	FEMALE CALVES	COW INPUTS	ACTUAL	PROJECTED	PROJECTED	ACTUAL	ESTIMATED AND PROJECTED [d]
	(Numbers)		(Real $)		[b]	[c]	(Kg)	
1963/64	5	22	2452	85			11468	11981
1964/65	3	21	2474	91	95	94	12636	12460
1965/66	7	23	2606	102	105	102	13286	13186
1966/67	15	28	2689	103	112	110	14059	13290
1967/68	20	30	2699	108	117	107	13964	13375
1968/69	23	33	2709	109	118	109	14618	13762
1969/70	21	33	2971	111	120	110	13032	13606
1970/71	20	32	3007	112	122	112	13300	14427
1971/72	15	30	3128	114	124	113	15720	15464
1972/73	20	31	3363	121	127	118	15425	14967
1973/74	24	32	3745	121	126	120	15281	15952
1974/75 [g]	30	35	2981	114 [e]	123	117		14845
1975/76 [g]	34	38	3897			109		16479
1976/77 [g] [h]	12	37	2769			100		14336 [f]
1977/78 [h]	4 [i] 46 [j]	34 [i] 40 [j]	2234 [i] 4502 [j]			115	12782 [i] 17510 [j]	
1978/79	2 [i] 41 [j]	32 [i] 43 [j]	2328 [i] 3847 [j]		136 [i] 95 [j]		12635 [i] 16618 [j]	
1979/80	0 [i] 40 [j]	30 [i] 44 [j]	2429 [i] 3569 [j]		156 [i] 84 [j]		12179 [i] 15553 [j]	

NOTES: (a) The decision variables have been estimated using the actual stock numbers and prices up to 1973/74.

(b) Cow numbers have been projected using the previous year's projected stock numbers and estimated decision variables and using the actual prices.

(c) Cow numbers have been projected using the previous year's actual stock numbers and prices and the estimated decision variables shown in this table.

NOTES TO TABLE C.2 CONT'D

(d) Milkfat production has been estimated using the cow inputs shown and the cow numbers projected under (c) but using actual farm area and rainfall.

(e) Provisional

(f) Milkfat has been projected using the projected cow inputs and cow numbers under (c) but with farm area held constant at 61 hectares and rainfall at the average for 1963/64 to 1973/74.

(g) The projections from 1974/75 to 1976/77 have been made using actual prices but using stock numbers projected under (c).

(h) The decision variables in 1976/77 and the cow numbers in 1977/78 have been projected using a 15 percent inflation rate in cow input costs.

(i) Projections from 1977/78 to 1979/80 have been made with all prices increasing by 10 percent each year. Rainfall used is the average over the period of estimation and farm area is held constant at 61 hectares.

(j) Projections from 1977/78 to 1979/80 have been made with the milkfat advance declining by 5 percent per year while all other prices increased by 10 percent per year. Rainfall and farm area are as for (i) above.

TABLE C.3 : THE EFFECT OF INCREASES IN PRICES ON VARIABLES

Variables	Effect with Average Prices	Effect with 10% Increase in the Average Price of:			
		Milkfat Advance	Cull Cows	Surplus Calves	Cow Inputs
Culls in Year 1 (No.)	16	15	16	16	17
Female Calves in Year 1 (No.)	29	29	29	29	29
Cow Inputs in Year 1 ($)	2793	2950	2802	2791	2969
Milkfat Production in Year 1 (kg)	13664	14052	13687	13659	14098
Cows in Year 2 (No.)	110	111	110	110	109
Cows in Year 3 (No.)	113	114	113	113	111
Cows in Year 4 (No.)	86	92	84	87	76
Cows in Year 5 (No.)	90	98	89	91	80

NOTE: The results have been rounded to the nearest integer.