The Economics of Maintaining Breed Diversity with reference to the United Kingdom dairy herd

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Table of Contents

Chapter 2 Literature Review

Chapter 3 Possible approaches to calculating the economics of diversity

Chapter 4 Formulation of the mathematical model

Chapter 5 Application of the linear programming model to the UK national dairy herd

Chapter 6 A Comparison of genetic improvments with breed substitution

List of Tables

Chapter 6

Chapter 7

Appendix A

List of Figures

CHAPTER 1 Introduction - the economics of diversity

1.1 Aims of the Thesis

The objective of this thesis is to look at, and consider the costs associated with maintaining diversity within the domesticated livestock (agricultural animals) population. Where possible, attention will also be given to some of the potential benefits from having diversity.

The value of this research is in its application of mathematical modelling and project appraisal techniques to a problem area that has attracted attention from the animal breeding and conservation communities. Much of the work already carried out has been on a very general level. It is intended that this analysis should focus on one specific sector - the United Kingdom dairy herd. Interest within the work will tend to be at the national rather than individual producer level.

This work has been carried out in collaboration with the A.F.R.C. Animal Breeding Research Organisation. Close contact has also been maintained with bodies concerned with aspects of livestock production - in particular the Milk Marketing Boards, the Meat and Livestock Commission, and some of the breed societies. Some information has also been obtained from manufacturers of animal feed.

The purpose of this chapter is to outline the structure of the thesis, giving an indication of what can be expected in the following chapters, and then to consider, with reference to a number of articles, some of the basic questions surrounding the need and uses of diversity.

1.2 Format of the Thesis

The subject matter of this thesis could best be described as multi-disciplinary - touching upon areas in economics, some of the principles of animal breeding and genetics, and lastly aspects of mathematical model building and project evaluation. As can be imagined, there is a considerable volume of literature on each of the above areas - none, however, encompassing all. Literature of relevance to the subject areas will be discussed in Chapter 2.

The concern of the thesis will then be how any evaluation of the costs and benefits can be carried out. Problems with apparently acceptable approaches will be discussed in Chapter 3.

Chapter 4 will focus on the construction of the mathematical model that has been developed to assist in evaluating the need for diversity. It is at this particular stage that the thesis switches its attention from the broad spectrum of all livestock sectors, to that of the United Kingdom national dairy herd. For the purpose of this thesis, the United Kingdom national dairy herd will be taken as all the herds of cattle in the UK which contribute to the national milk output.

The following two chapters will centre around the application of the model, trying to answer the question of whether or not diversity is actually needed, and,if so, determining the optimal form in which it should be kept given certain possible events. The main purpose of the mathematical model will be to calculate the optimal breed structures - the costs associated with altering the existing breed structure will be compared with the costs of achieving the necessary alteration through genetic improvement of the existing herd structure.

At this stage, reference will be made to the possible effects on both methods of adapting the national herd of technologies which are currently in the development stage . The consequences of these technologies will be discussed with reference to the costs associated with breed substitution and genetic improvement.

The final chapter will then try to summarise what has been discussed in the thesis, highlighting problem areas, as well as pointing out potential areas for further research.

1.3 The need for Diversity

1.3.1 Introduction

With man being dependent upon food for his survival, combined with the fact that the world's population is expanding, continual efforts are being made by agricultural producers to improve their methods of production and the resultant level of output. This desire to improve production is not just of recent years, but is now supported by a wealth of scientific knowledge and research.

In the course of their efforts, little attention has been paid, until recently, towards the consequences of their actions vis a vis the long term. Concern is now being expressed in both the Developed and Developing regions of the world that in the process of improvement, genetic diversity is being lost (Bowman (1974), Miller (1977) and Maijala (1974)).

As can be seen from the dates on some of the literature, the need for diversity has been the subject of discussion for at least the last decade. The need for diversity has been split into three categories (Mason (1974)):

- agricultural;
- scientific;
- cultural.

Prior to looking at some of the reasons given for the need for diversity, it is pertinent to note what is actually being referred to by the term 'diversity'. Dictionary definitions of the word usually include phrases such as 'being diverse', 'different kind' and 'variety'. In the context of this thesis, diversity will be taken as both recognisably different breeds and genetically different strains.

1.3.2 Agricultural needs for Diversity

One of the major arguments used in favour of maintaining diversity in livestock population is that the selection processes used by breeders can result in the reduction in genetic variation. Without variation further improvement or changes are difficult. If, however, a reserve of material were available, it would have either of two uses:

(i) to break through a selection plateau *, thereby allowing further improvements through selection;

(ii) to facilitate a sudden change in selection goals or environmental factors.

Barker (1980) added a further argument in favour of diversity in the context of the role it can play in the Developing Countries. In attempts to improve the agriculture in the Developing Countries, some of the exotic European breeds have been introduced to the indigenous breeds. Providing it is done with care, such work can be beneficial. It is harmful, however, when the new breeds replace the native breeds. Such action can result in losing the natural resistance to local

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* See glossary of terms

parasites and the mere ability to survive in the environment. Ipsen (1972) quotes a number of examples when breeds have been introduced to populations, helping to improve output.

1.3.3 Scientific uses for Diversity

One of the justifications for conserving diverse material given by Mason (1974) under this category was that animals adapted to bizarre diets, unusual habits or specific parasites can provide fundamental raw material for various genetic or physiological studies. A further factor in favour of diversity relates to the benefits of genetic research. If material is available for research, there is the possibility that genes which confer resistance to a disease pathogen or parasite could be identified. The benefits from such work could be substantial in the long term .

Preserved genetic material also has a use in providing a control population, which enables genetic changes in a livestock population to be identified separate from environmental shifts. Mason (1974) also argued that maintaining particular breeds enabled scientists to understand better the origin and relationship of breeds, as well as providing invaluable information in tracing the history of domestication and interpreting the findings of archaeologists.

1.3.4 Cultural arguments for Diversity

Justification for maintaining diversity could be argued solely from the social viewpoint, playing on the stigma that surrounds breeds and species such as the dodo. If we allow a breed or strain to disappear, we have lost part of our heritage forever.

The intention of this thesis, however, is to try and disregard this last argument, and examine the costs and benefits associated with maintaining diversity.

Having discussed some of the major arguments cited in favour of maintaining diversity, it is pertinent to look at points which could be raised against using various resources for the purpose of conservation.

1.4 Arguments against Diversity

Published arguments against allocating resources to keeping diversity appear to be few in number. McInerney and Hallam (1982) make the point that the phenomenon of 'becoming rare' is surely an indication of economic obsolescence, and therefore is not, on its own, a basis for ensuring its continuation. They do go on, however, to say that the argument of whether or not it is worth maintaining a breed or stock depends upon its potential contribution to improving production in the future.

A second argument that could be employed in the argument against conserving genetic material revolves around the point that if a suitable and well organised national breeding programme was used, additional genetic material should not be necessary. Bogart (1959) listed a number of points that should be considered when carrying out selection. The factors of importance should not only include production levels, but also things such as fertility and freedom from defects. This does not mean to say that the characteristics listed by Bogart (see Table 1.1) are not already considered in either selection processes or in evaluating sire performance. It could suggest, however, that too much importance is put on some characteristics, at the expense of others.

Table 1.1 Important characteristics for selection of farm animals (Bogart 1959).

<u>Cattle</u>	- Level of fertility;
	- suckling ability;
	- post-weaning gains;
	- feed efficiency;
	- live animal merit;
	- freedom from inherited defects.
<u>Sheep</u>	- fertility;
	- milk ability of ewes and growing capacity of lambs;
	- conformation *;
	- wool;
	- freedom from inherited defects.
<u>Swine</u>	- fertility;
	- mothering ability;
	- growth rate;
	- feed efficiency;
	- conformation;
	- freedom from inherited defects.

* See glossary of terms

Another argument that could be used against maintaining a stock of diverse material, focuses on the question of how much difference it would make if a situation arose requiring alterations to be made to the existing herd. Irrespective of what forms the reserve was kept in, there would be a lag between when the need for it (or part of it) became apparent, and when it could be disseminated into the herd. It could well be the case that alternative measures could be found, such as changing management and husbandry practices, which are cheaper and easier to affect.

Adding to the above argument is the matter of how permanent is the change that requires diversity. Bogart (1959) makes the point that breeders should adopt a goal and stick to it - selecting accordingly - and ignore the short term changes which might occur and appear more financially attractive. The goal suggested is the economical and rapid production of good quality products. Adopting such a goal could be beneficial - however, if producers totally ignored the need for changes, the results could be fairly bad, both for the producers and the country as a whole.

A final argument in this section revolves around whether or not we do actually need diversity. If one looks at the current livestock population, there are in all sectors in the UK at least two or three different breeds used in commercial production. In addition, there are a number of other breeds and strains maintained in small units by the hobby/enthusiast type of farmers. Viewing the situation at the international level, the existing level of diversity increases substantially. The answer would appear to be, therefore, that at present we do not need additional diversity. The trend within certain livestock populations, however, would appear to be moving towards the dominance of one or perhaps two breeds for each sector. Because of the uncertainty of future events and consumption requirements, it is not possible now to say, with any certainty, whether these chosen breeds will best meet future needs.

1.5 Further questions on Diversity

If one accepts the premise that some form of diversity should be kept for possible future use, there are four questions which need to be asked:

(i) what should be maintained?
(ii) how should it be maintained?
(iii) who should be responsible for ensuring an adequate reserve is kept?
(iv) what are the costs and potential benefits involved?

All four of the above points will be discussed in the remainder of this chapter.

1.5.1 What should be maintained

It is not intended for this section to list breed by breed what should actually be kept, but to mention and discuss some of the principles.

Smith (1984) suggested four guidelines on conservation - namely:

(i) to conserve many stocks in small amounts;
(ii) to conserve stocks which are a genotypically and phenotypically* as diverse as possible;
(iii) to store the stocks as pure lines rather than as gene pools;
(iv) to preserve locally adapted stocks which are best suited to special niches and conditions.

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*See glossary of terms

A comparable list of what should be kept was suggested by Mason (1974), but with the emphasis more on breeds than on genetic strains. A summary of this second list includes:

- indigenous breeds uniquely adapted to the environment, or showing hybrid vigour* when crossed with exotic breeds;

- local productive breeds little known outside their home country;

- bizarre or beautiful breeds which would attract attention on exhibition;

- historically important breeds.

The magnitude of any undertaking to preserve all the endangered breeds was recognised by Miller (1977), who listed 47 breeds of cattle in Europe and the Mediterranean Basin which he classed as being in a 'relic state'. As a solution to the enormity of the situation, Miller (1977) proposed that, as many of the breeds were similar, the criterion of genetic uniqueness should be used.

Moving away from the theme of identifiable breeds or genetically unique strains, Land (1981) suggests that if diversity is to be kept, it should be in the form of divergent genetic lines. Part of the reasoning behind this recommendation is that opportunities for genetic change are dependent upon the extent of genetic variation available. If similar genetic lines were kept, improvements either side of the lines could be difficult, and take longer to achieve.

When making the choice of what should be kept, the approach used could be along the lines of portfolio theory. What is required is a collection of material such that, should a

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* See glossary of terms

situation arise at some point in the future requiring changes to be made to the national herd, the chance of incurring large losses is minimised.

1.5.2 How should Diversity be maintained

There are basically three methods of maintaining diversity outside the commercial herd:

(i) maintenance of flocks or herds in farm parks or zoos;
(ii) storing of frozen semen;
(iii) storing of embryos.

As can be imagined, each method has various advantages and disadvantages.

1.5.2.1 Farm parks or zoos

In the United Kingdom, efforts are being made to conserve herds of breeds that are classified as rare, through work done by the Rare Breeds Survival Trust (R.B.S.T.). The objective of the R.B.S.T. is to conserve animal genetic resources by operating farm parks (run along similar lines to a zoo) and by collecting and storing semen from classified rare breed bulls. (The semen storage operation is being carried out with the assistance of the Milk Marketing Boards.)

The R.B.S.T. classify the status of breeds (that is, how close to extinction they are) using different categories. At present they have over 40 breeds of livestock that they class as being on the danger list.

Although maintaining diversity using this method has the advantage of being able to supply a stock of live animals from which to breed directly, it would be an enormous undertaking to preserve herds of all endangered breeds. To be safe from

possible loss due to disease, maintaining diversity in the form of live animals would require at least two separate herds for each breed.
An indication of the size of such an undertaking can be obtained from Table 1.2, which gives the recommended numbers for a single breeding stock (Smith (1984a)).

1.5.2.2 Storing of frozen semen

Advances have been made in the technology enabling semen to be collected, frozen and stored. Difficulties do still appear to exist with regard to pigs and poultry which make the costs of collecting and storing semen (effectively) comparatively high. Large stores of cattle semen already exist, and international trade in semen appears to be a growing profitable business. Unfortunately for the context of this research, most of what is being stored is from the currently popular breeds.

The major disadvantage with storing diversity in the form of semen is that to obtain a purebred animal requires several backcrosses*, unless a female of the same breed already exist. The advantages are its low costs, and with cattle, its ease of collection and storage.

1.5.2.3 Storing of frozen embryos

Collecting and storing embryos is only currently possible for cattle and sheep. This method of maintaining a stock of material has the advantage over semen in that the required product can be purebred from the first new generation (provided it is stored in a pure form), thus doing away with the need for repeated backcrossing.

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* See glossary of terms

Table 1.2 Recommended size of a single breeding unit (keeping the level of inbreeding down to 0.2% per year).

	Cattle	Sheep	Pigs	Chicken
Male	10	22	44	72
Female	26	60	44	72

One of the disadvantages with storing embryos is that there appears to be a limit to how many embryos can be obtained from each female without causing damage to the donor. Another disadvantage with embryo transfer is that it can increase the level of inbreeding* in a herd (Dalton (1980)).

1.5.3 Who should be responsible for ensuring and maintaining Diversity

The question of who should be responsible for maintaining diversity would appear to depend on the country concerned. Mason (1979) suggested four alternative methods:

(i) Private initiative - which is the principal method of conservation currently employed in the United Kingdom and United States of America. In the UK there is the R.B.S.T., who not only assist with the running of farm parks, but have also managed to establish a gene bank, in the form of semen, with the assistance of the Milk Marketing Boards. The cost of storing this semen is very low.

(ii) Government initiative - in Eastern Europe, any conservation herds are kept on state farms.

(iii) Government subsidies - this method is currently favoured in France and Italy.

(iv) Zoological gardens.

All arguments surrounding whether or not we need diversity, and if so in what form, and who should be responsible for it are really dependent upon how one views the future. Keeping diversity in some form is basically an insurance policy against possible future changes. With the uncertainty of whether or not any part of the reserve would have any value, it is unlikely that private companies would get involved solely with establishing reserves of diverse material.

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*See glossary of terms

As already mentioned, there are companies within the United Kingdom and North America, who are involved with buying and selling semen and embryos of the currently commercial breeds. There would appear to be little demand at present for semen and embryos of the currently non-commercial breeds. If a concerted effort is to be made towards maintaining diversity, therefore, it would really need to be financed either directly or indirectly by the government or an international organisation, such as the Food and Agriculture Organisation (F.A.O.).

1.5.4 The costs and benefits of maintaining Diversity

The objective of this section is to outline some of the cost areas and potential savings that could be the result of maintaining diversity. It is not intended that figures should be discussed to any great extent - this will be done in later chapters.

In the subject of costs, there are two main areas - that of actually collecting and storing the diversity in its appropriate form, and the costs associated with actually introducing the diversity into the national herd.

1.5.4.1 Costs of collecting and storing Diversity

The costs of collection and storage are largely dependent upon how the diversity is to be kept, and in what amounts. Actual costs associated with collection and storage of semen and embryos are fairly accessible, but relate to the current popular breeds. There would appear to be no particular reason why costs associated with the less popular breeds should be any greater aside from those directly associated with the scale of the operation.

The costs of maintaining diversity in the form of a breeding stock depends, to a certain extent, on one's definition of 'cost'.

The actual costs of input, such as labour and feed, would probably not differ to any great extent from the costs of running a commercial herd of the same size, unless, of course, an unusual diet is required. Taking an opportunity cost approach, however, the cost of maintaining a breeding unit is the difference between the net income from operating with a commercial breed, and that from keeping a non-commercial breed.

A further cost area that could be incurred, associated with collecting and storing diversity, are costs linked with testing and improvement work. The problem with estimating the costs of any testing or evaluation programme is that the magnitude of costs involved is partially dependent upon the traits for which any selection programmes are based. Costs relating to current selection programmes are for work based around traits of commercial importance now. It is not really possible to predict with any certainty what traits will be of importance in the future, making the quantification of costs slightly difficult.

1.5.4.2 Costs of introducing Diversity

The costs of introducing diversity to the commercial herd depend on several things:

- the structure of the industry - by which one means the paths available for disseminating improved stock into the commercial herds;
- the extent and urgency of the changes which have to be made;
- the willingness of the industry to accept and adapt to changes;

- the form in which the diversity is kept.

The first and last of these factors are really inter-dependent - if the diversity is maintained in the form of semen and/or embryos (and providing sufficient quantities are kept) the reserve could be transferred directly into the commercial herds. Land and Hill (1975) stated that in certain circumstances the rate of genetic change can be increased by 50%-100% using embryo transfer. If the diversity is maintained in the form of live animals, or insufficient suitable germ plasm * is available, a multiplier stage would be required.

Bichard (1971) identified five alternative structures for disseminating improved stock into the national herd. The traditional structure consists of three tiers - the **nucleus** (N), from which genetic improvement originates, the **multiplier** (M), which multiplies stock from the nucleus to be passed into the third stage, the **commercial** producers (C).

With the advances that have been made with embryo transfer and artificial insemination, two tier systems are possible in most of the livestock sectors (see figure 1.1).

In the United Kingdom, there already exists an effective dissemination system for cattle, with a large proportion of the semen that is used coming from the Milk Marketing Boards, who supply semen for beef cattle as well as the major dairy breeds. The sires used by the Milk Marketing Boards for supplying semen to producers are subjected to extensive tests and evaluations, checking on a range of characteristics.

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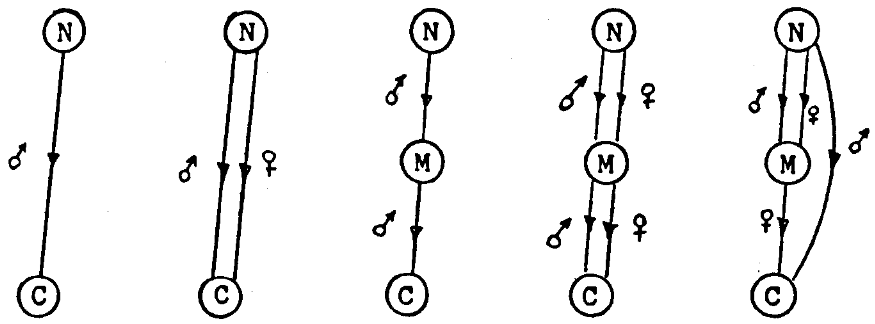
* See glossary of terms

Figure 1.1 **Alternative paths for disseminating improved stock into the national herd**



♂ male stock

♀ female stock

N = Nucleus herd

M = Multiplier

C = Commercial herd

The extent of the changes to be made is dependent upon the proportion of the required genes that are already present in the commerical population, whereas, the urgency of the changes relates to the extent of the necessary alterations and the costs involved with operating sub-optimally.

The area that is difficult to quantify is that of the producer's willingness to adapt their present mix of breeds or strains. The speed at which any changes will be effected is dependent upon factors such as how quickly the improved stock can be made available, and the financial incentives involved. Both these areas will be discussed in further detail in later chapters.

1.6 The consequences of not having Diversity

In the previous section some of the costs linked with having diversity were mentioned. Prior to moving away from the introductory phase, it is worthwhile to mention some of the cost areas and consequences associated with having no reserve of diversity either in the national herd, or available in store.

The main consequence from having no additional diversity would be that if the need for altering the breed structure arose the national herd would be forced to operate for longer at a sub-optimal level, in so far as the industry concerned would be in a state of either over or under production of some, or all, of its products. The actual costs related to such an outcome will be discussed in later chapters.

The major area for discussion and examination with regard to having no diversity is that of when the supply from domestic production is unable to meet demand. In such a case, consumers would be forced to either obtain the required product (or products) from elsewhere (if it was available at an acceptable price), or look for a suitable subsitute, or change their pattern and style of consumption. If market value were to drop, and failed to recover after the necessary changes had been effected in the national herd, this could be classed as a cost of having no additional diversity.

1.7 Conclusion

In this chapter, some of the arguments for and against maintaining diversity have been mentioned. This has been done without any preference for either side of the discussion being expressed which will come in later chapters, supported by the appropriate calculations which will take into consideration the costs of having diversity, and the costs incurred through lacking any.

There are certain advantages in maintaining diversity in the form of either semen or embryos. At present, however, technical difficulties make the collecting and storing of pig and poultry semen expensive. Embryo collection and storage is also only possible at present with cattle and sheep. It will only be a matter of time, however, before these problems are solved. Therefore, if diversity were to be kept for all domesticated livestock now, a combination of all the methods mentioned would be necessary. Keeping diversity on farm parks, in limited numbers, has been proved to be possible by the Rare Breeds Survival Trust.

Part of the problem with evaluating the economics of diversity is the identification and quantification of costs. Information regarding the cost of keeping diversity in its various forms is currently available, but calculating the costs of introducing it to the herd will require careful consideration of a number of factors. Predicting the benefits from diversity is a further area of difficulty - one approach that could be used is to quantify the benefits as being equal to the costs that would be incurred if there was no diversity in the national herd.

The remainder of this thesis will attempt to evaluate the economics of diversity, comparing the option of breeds versus genes. When ascertaining whether a need for diversity exists, the main area for attention will be possible events which could result in producers, as a whole, changing their selection goals.

CHAPTER 2: Literature Review

2.1 Introduction

Some of the basic questions and points surrounding the subject of maintaining diversity in the agricultural livestock herds were touched upon in the previous chapter. It is intended that this chapter should review some of the literature relating to the main areas that will be used in the evaluation processes later in the thesis. The subject areas that will be covered include aspects of mathematical modelling, economic analysis and evaluation, and animal breeding.

Initial discussion will focus on various theoretical aspects of modelling techniques applicable to the situation. Later discussion will concentrate on specific modelling applications concerned with livestock production. At this point, particular reference will be made to the modelling of dairy cattle systems.

2.2 Modelling Techniques

2.2.1. Introduction

The theoretical aspects of the use of mathematical modelling techniques has been well covered in specific literature, where features are discussed in fairly general terms - for example, contemporary texts such as Levin and Kirkpatrick (1978), Loomba (1978), Buffa and Dyer (1978), and Hull, Mapes and Wheeler (1976). It is intended therefore not to examine in great detail the theories behind the techniques, but to concentrate more on the methodologies available, and their applicability to the problem being tackled.

The choice of which modelling technique to apply is really dependent upon two factors - firstly, what the modeller hopes to achieve from the analysis, and secondly, to what extent usable information is available.

Buffa et al (1978) outlined three major categories of models:

(i) Evaluative - how things ought to be done;
(ii) Predictive - how things work;
and (iii) Optimizing - what is best.

The category of interest in the context of estimating the economics of diversity is the third, namely optimization. The reason for this choice is that what we wish to try to determine is whether or not it is beneficial to keep a supply of diverse material, and, if so, whether it should be breed or gene diversity.

A possible alternative modelling approach that could have been applied is simulation. Ploumi (1981) and Gartner (1981) applied simulation techniques to livestock production systems. The attraction of simulation modelling is that it can be particularly useful for evaluating natural systems which contain an element of uncertainty. Simulation,however,is not the best method for determining which of a series of possible strategies is better, in that it focusses more on what happens rather than what is optimal.

2.2.2 Optimization techniques

There are a number of alternative types of optimization techniques available, the most common being the linear programming approach (which can also include integer programming), dynamic programming and quadratic programming. As its name suggests, quadratic programming primarily differs from linear programming in that it is applicable where the objective function is non-linear, or cannot be approximated as linear.

Dynamic programming is a technique used to make a series of interrelated decisions which together give the overall optimum. Decisions made at each stage influence not only the following stage, but also each subsequent stage. Dynamic programming is only suited to particular problems. Shamblin and Stevens (1974) suggest that use of dynamic programming is not really feasible for a problem with more than three variables, in that if there are n stages, with m possible conditions at each stage, there would be m^n feasible answers. With the increased availability of computers and software packages, however, larger problems can be tackled. Glen (1983), for example, applied dynamic programming to the problem of determining the optimal feeding policy to produce pigs of a specified weight and carcase composition. Stewart, Burnside and Pfeiffer (1978) used the technique to calculate optimal culling strategies in a dairy herd.

The main characteristic difference between dynamic and other mathematical programming techniques is that dynamic programming tends to start with the required final situation and work backwards, making optimal decisions at each stage of the problem. Dynamic programming is best suited to large complex problems which can be broken into a series of smaller problems.

Nagel and Neef (1976) described linear programming (also known as linear optimization) as being a procedure whereby one can find the optimum allocation of resources between two or more options, in the light of certain objectives, and subject to given constraints or conditions.

Moskowitz and Wright (1979) considered that a linear programming (L.P.) problem should have four basic properties:

Proportionality: - The objective function and every constraint on the decision variables must be linear, or a suitable linear approximation.

Additivity: - It is essential in an LP model that each variable is additive with respect to profit (or cost) and to the amount of resources used.

Divisibility: - Fractional levels of decision variables must be allowed, otherwise integer programming techniques should be applied.

Optimality: - An optimal solution exists, subject to the constraints and boundaries imposed. (The topic of optimality will be discussed in more detail shortly.)

Although very flexible, LP is not without its drawbacks. Unless care is taken when identifying relationships and formulating the model, it is very easy to make over simplifying assumptions at the expense of accuracy and reality. It is, however, a very popular, powerful tool because of its flexibility, enabling fairly extensive sensitivity analyses to be carried out without excessive computation.

2.2.3. Handling of risk and uncertainty

The choice of modelling technique adopted in this analysis has to allow for a certain element of risk and uncertainty because of the subject matter. Although simulation is suited to modelling situations which involve random events, its use will be avoided partly because of the difficulty involved with its application, but also because simulation does not give the flexibility required.

Dynamic programming can be used to handle probabilistic problems (Levin et al (1978)), but involves excessive computation. Linear programming type models can allow for risk and uncertainty in a number of ways. Kennedy and Fransisco (1974) outline a number of alternative approaches to formulating risk constraints advocated by a number of authors. These are:

(i) Markowitz - The expected total gross margin/dispersion analysis, also known as the Portfolio selection or Expectation-Variance (E-V) approach.

(ii) Hazell - The use of Games Theory approaches.

(iii) Roy - Using safety first constraints.

A similar type of article by Boussard (1979) outlines two traditional approaches to dealing with uncertainty in agricultural programming models. The approaches suggested correspond to method (i) and (ii) suggested by Kennedy et al (1974).

The Portfolio selection type model assumes that the investor considers an investment in terms of a probability distribution of its portfolio returns. It also assumes that any decisions involve only consideration of the expected return and the risk associated with an investment. Risk is measured by the dispersion of the distribution or variance of the returns. The choice of which portfolio or combination of investments is selected therefore is dependent upon which set of assets is best suited to the investors preferences, trading risk off against return.

Portfolio selection modelling has a number of weaknesses and disadvantages, some of which have been highlighted in a number of articles.

(i) Boussard (1979) raises the point of how can the risk aversion coefficient be measured, and what significance does it have.

(ii) The use of variance as a measure of risk implies that the distribution of returns is symmetrical, which is not always the case (Dickinson (1974)).

(iii) The Markowitz model requires knowledge of the expected returns and the variance of each asset in the portfolio, as well as the covariance of each pair of assets. If this information is not directly available, approximate values have to be obtained from existing comparable investments. As Koutsoyiannis (1982) points out, if there are n assets, information is needed on n returns, n variances and $(n^2 - n)/2$ covariances, which for a portfolio of 50 assets, would mean 1,325 calculations.

A more practical version of the Markowitz model was developed by Sharpe (1963), which he admits, however, is only really suitable for a preliminary analysis.

Boussard (1979) discusses various other E-V type models which include the safety first approach (which Kennedy et al (1974) classed as a separate category), and a variety of unorthodox approaches.

The safety first approach works on the assumption that the decision maker maximises expected income, subject to some specified probability of obtaining a minimum level of income (Roy (1952)).

The unorthodox approaches discussed by Boussard (1979) include MOTAD and FLCP. The objective of the mean absolute deviation of the total gross margin (MOTAD) is to minimise the mean absolute deviation of the total gross margin, whereas the

Markowitz approach minimises the variance for any total gross margin. The focus-loss constrained programme approach (FLCP) is based largely on the safety first approach.

As a conclusion to the review of various E-V modelling approaches it is interesting to note that Merril (1965) used four alternative methodologies to solve a multi-time period model. Of the methodologies used, three were various risk programming models with the fourth being an LP model without any risk constraints. The results obtained from the four different approaches were not very dissimilar. Hazel, Norton and Parathasarathy (1978), however, suggest that failing to include some measure of risk aversion can result in specialised higher risk cropping patterns being favoured rather than a broader, safer spectrum of crops.

The other approach to dealing with uncertainty suggested by both Boussard (1979) and Kennedy et al (1974) was that of the theory of games. The general conclusion of games theory is that a farmer's decision should be treated as a two person game, with the farmer as one player - the other player being nature. It has also been suggested that many decision making situations can be described as zero-sum games (Makower and Williamson (1975)). The implication of zero-sum games is that what one player loses, the other gains. The applicability of this view is questionable in the context of this thesis.

A more relevant argument against using games theory is its lack of flexibility in comparison to linear programming. Mitchell (1972) listed six conditions which must exist before games theory can be applied, one of which was that all possible outcomes should be calculable. Although this also applies to linear programming, using L.P. sensitivity analysis techniques allows the boundaries between different possible solutions to be determined with greater ease.

A third approach, so far unmentioned, for dealing with the problem of risk and uncertainty is parametric programming. In technical terms, parametric programming involves examining the effect of altering either the coefficients of the objective function, or the range of solutions over which the shadow prices hold (Hayhurst (1976)). Expressed in a more straightforward manner, the technique involves looking at how much costs on the one hand, and factors affecting output on the other, have to change before the initial solution calculated is no longer the best possible.

Before a choice of which of the above approaches to adopt in the modelling process can be made, it is necessary to consider what is required, and what the above methods can be used for. The system being modelled is agricultural, and therefore subject to a degree of uncertainty - uncertainty in that output in any one year cannot be predicted precisely. There is added uncertainty through the nature of this particular analysis in that all the potential needs for, and benefits from, diversity cannot be determined precisely.

It is necessary at this point to highlight the distinct difference between risk and uncertainty. Risk is where the various possible outcomes are known and, by various means, reasonably realistic probabilities for the likelihood of each outcome occurring can be obtained. Uncertainty is where there is a degree of subjectivity involved in arriving at probability values. Makower (1974) identified a third state - ignorance - which exists when it is not possible to even try to calculate probability values.

Taking these points into account, it is therefore infeasible to consider the use of the portfolio theory type of approach for this particular problem. Portfolio analysis involves the analysis of risky situations, and no previous information exists for situations requiring comprehensive stores of genetic material from which the values required could be calculated. By adopting the parametric programming approach one is acknowledging that it is not possible to predict precisely what changes are likely to occur requiring additional diversity. A number of alternative scenarios can be examined which may provide a range of outcomes from which to argue the case for and against diversity.

2.2.4. The objective function

Having discussed a variety of possible approaches to handling risk and uncertainty, it is relevant to focus attention on the matter of the criteria used for any decision making process. The objective function specifies the criterion to be used in determining the goal of the model. The traditional criteria used are either maximisation (usually profits or output) or minimisation. There are, however, a number of alternatives, some of which are dependent upon whether the situation being examined involves either risk or uncertainty (Levin and Kirkpatrick (1978)).

The decision criteria associated with conditions of uncertainty are:

(i) Maximax: - where the decision maker adopts the strategy which maximises the maximum benefit or profit.

(ii) Maximin: - maximising the minimum profit possible.

(iii) Minimax regret: - minimising the maximum possible regret. The regret being the difference between what could have been achieved, had the future state been known, and what was actually achieved.

(iv) Criterion of realism: - midway between maximax and maximin criteria, and involves specifying a coefficient of optimism, (a value between 0 and 1), such that:

$$\text{Measure of realism} = \alpha(\text{max. payoff}) + (1 - \alpha)(\text{min. payoff})$$

This criterion allows subjectivity to be introduced to the decision making process.

Some of the decision criteria applied to situations involving risk are:

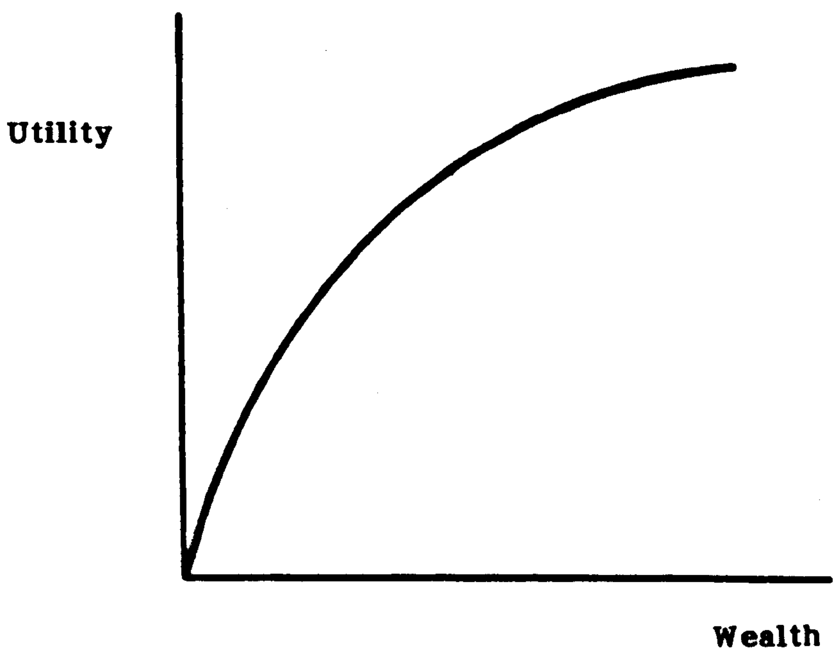
(i) Expected value: - this requires the decision maker to calculate the expected value for each possible alternative. The expected value is calculated by multiplying the profit or outcome from each state, by the probability of that state occurring, and the optimum strategy is the one resulting in the greatest expected profit.

(ii) The criterion of rationality: - sometimes referred to as the principle of insufficient reason. This assumption works on the basis that, in the absence of information to the contrary, an equal probability is applied to each of the possible states or events.

(iii) The criterion of maximum likelihood: - this involves the decision maker selecting the event that has the highest probability of occurring, and then selecting the strategy which will give the highest payoff for that event.

In addition to the above mentioned approaches there are a number of further possible criterion, one of which involves measuring the outcome in terms of utility rather than in physical terms (such as amounts of money). An individual's utility curve depends upon a number of factors - expectations about the future, how one views profit or loss and the decision in question. Figure 2.1 represents the utility function of an individual averse to risk. An individual averse to risk obtains increasingly smaller levels of utility

Figure 2.1 Utility function of a risk averse individual



from each additional unit of health. Individuals can have different utility functions for different situations (Levin et al (1978)).

The final decision criteria which warrants mention that could be applied is that of satisficing. This is fairly similar to the concept of using utilities in that the decision alternative adopted need not be the overall financial optimum. The decision process in this case is constrained in some way, either by a physical constraint such as insufficient resources necessary to achieve the optimum, or by the decision maker making a trade off between the benefits from achieving additional output against not wishing to increase the level of input.

2.3 Modelling Application

2.3.1 Introduction

Having discussed certain aspects relating to the methods of mathematical evaluation available, it is relevant to focus on specific instances of the application of modelling techniques to animal production systems.

The purpose of the proposed model is to investigate possible states of a livestock sector which could result in the need for additional diversity. Additional diversity in this context will be taken to include breeds or strains currently not available in significant proportions in the relevant livestock sector.

The basis of the model (which will be described in detail in Chapter 4) will be such that supply will be constrained to at least meet a certain level of demand. Attention will be focussed on the supply aspects.

Supply is basically dependent upon two factors - the number of animals involved with production, and the usable output per producing animal. These give two initial areas requiring modelling. All evaluation will be done at the national level.

2.3.2 Numbers in the national herd producing

For a single time period the supply function is comparatively straightforward. When considered over a number of time periods, however, the model develops problems and complexities. An idea of the complexity of the situation involved with calculating total numbers in a national herd can be obtained from figure 2.2 (Brockington (1979)). The flow chart shows some of the relationships that would need to be considered in the evaluation of the need for diversity. From the chart it can be seen that the number of animals in the herd is influenced by the culling, replacement, and breeding strategies employed.

2.3.2.1 Culling

For our purposes, the term culling will refer to animals that were involved in production in the national herd and have subsequently been withdrawn. Some animals are sold before entering the adult herd - the level of sales is related to the number of replacements necessary and will be discussed at a later stage.

From the literature three main ways have been used to tackle the problem of the number of adult animals culled:

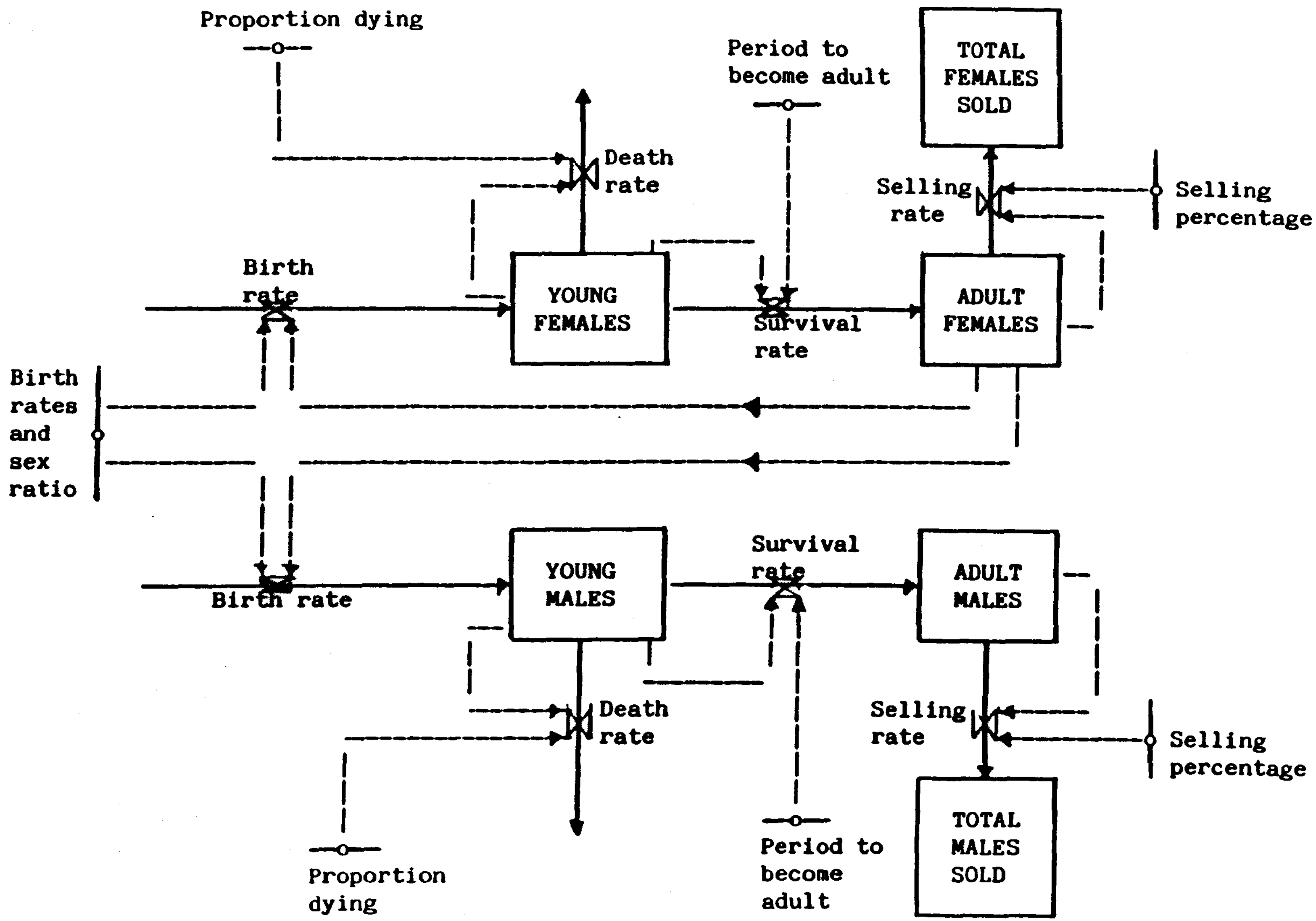


Figure 2.2 **Factors influencing the number of animals in a herd**

(i) The number culled is set equal to the number entering the herd several periods earlier. The Centre for Agricultural Strategy (C.A.S.) Report (1978) adopted this approach, with the number culled equalling the number of heifers retained five periods earlier.

(ii) Use of a percentage of the total population, for example Gartner (1981) and McFarquahar and Evans (1971). The figures are usually taken from surveys carried out over a number of periods.

(iii) The number culled is defined as a function of a number of variables. Asdell (1951) stated that the reasons for disposal of dairy cattle vary with time and are a function of the health status of the herd, fluctuations in the beef and milk markets, the demand for breeding stock, as well as a number of other factors.

Dynamic programming studies have been undertaken in order to determine the optimal culling strategies - for example Stewart, Burnside, Wilton and Pfeiffer (1977). These studies however require probability studies of reasons for disposal.

Gartner and Herbert (1979) used the principle that culls should be classified as either culled for yield or for other reasons. It was found that the probability of a cow being culled for reasons other than yield falls equally on animals of the same lactation group, and increases with the number of lactations the cow has completed. The probability of a cow being culled for insufficient yield depended upon the number of lactations completed. The number of cows culled for yield, however, was also constrained by the replacement rate and the number of unpredicted culls.

Young, Lee and Waddington (1980) carried out a survey of culling in Friesian herds. Of the herds in the survey, 25% of the cows survived for more than 7½ years, and 25% were culled before 3¼ years. The results showed that the average length of a cow's life was about 3½ lactations or 5½ years.

The ideal methodology would be along the lines suggested by Asdell (1951), but indications suggest it would require substantial modelling. Using percentages as culling rates would appear to be an acceptable approach to the problem. The problem arises, however, in deciding what the rate should be. As can be seen from table 2.1 (Burnside, Kowalchuk, Lambroughton and Macleod (1971)) the rate calculated from surveys can differ considerably.

Despite the problems of determining which rate to use, this latter method will be the one employed in the model. Reasons for this decision will be made apparent when the model is discussed in detail in Chapter 4.

2.3.2.2 Replacements

The question of the number of replacement heifers introduced into the herd is slightly easier than that of the number leaving (culls and deaths), in so far as there is more of an element of choice with the replacements than culls. In the M.M.B. Survey (1971/72) only 25% of the culls recorded were voluntary.

Perhaps the most explicit modelling done in this area was by Mcfarquhar and Evans (1971) who described the number of male calves kept as being a function of the average guaranteed price and the market price for beef cattle. The number of female calves kept was defined as being a function of the producer price for milk, the average market price for the clean fat cattle and the calf subsidy.

Table 2.1 Summary of research on dairy cow disposals (Burnside et al, 1971)

	1	2	3	4	5	6
Breed	Holstein	Holstein	Holstein	Jersey	Jersey	5 breeds
No. of cows	505	1861	7317	503	3505	7362
Period of study	1918-58	1949-66	1958-63	1961-62	1961-62	1960-61
Reasons for disposal:						
Dairy purposes %		12.4	9.6	16.9	39.3	14.2
Breeding problems %	33.4	30.3	15.7	14.5	13.2	16.1
Milk production %		22.1	36.9	26.4	14.5	27.1
Mammary system %	8.5	2.9	13.5		3.6	6.1
Type %		0.8		10.5	2.6	2.0
Mastitis %		8.0	5.8	13.9		8.3

References:-

1. Parker, Bayley, Fohrman & Plowman, 1960. 'Factors affecting dairy cattle longevity.' J. Dairy Sci. 43, 401 - 409.
2. Hargrove, Salazar & Legates, 1969. 'Relationships among first lactation and Lifetime measurements in a dairy population.' J. Dairy Sci. 52, 651 -656.
3. White & Nicholas, 1965. 'Reasons for disposal of Pennsylvannia Holstein cattle.' J. Dairy Sci. 48,512
4. Fosgate, 1965. 'Rate, age and criteria for disposal in a herd of registered Jersey cattle.' J. Dairy Sci. 48, 1481 - 1484
5. Rennie; 1965. 'Variation in length of productive life of Jersey cows in North America.' Proc. 5th Conf. of the World jersey Cattle Bureau New Zealand Feb. 1965.
6. O'Bleness and Van Vleck, 1962. 'Reasons for disposal of diary cows from New York herds.' J. Dairy Sci. 45, 1087 -1093.

The number of heifers retained in the herd was defined as being a function of the average guaranteed prices for beef cattle and milk, the average price of concentrates and the cow subsidy. C.A.S. (1978) adopted a similar approach, defining the number of heifers entering the dairy herd as a function of the producer receipts for milk and the price of concentrates.

As with culling strategies, replacement numbers have been calculated using fixed percentages - for example, Gartner (1981). This does, however, once again raise the problem of what percentage figure to use. Hill (1971) suggested a method where the number of replacements in a particular year was set as being equal to the number of replacements four years previous, plus a price variable.

Ploumi (1981) described the probability (p) of a heifer being kept in the herd as a function of the number of replacements needed (k) and the number available (n). If k is greater than n, there should be no selection between heifers, and p=1. If k is less than n, that is the number available exceeds the number needed, a proportion (n-k)/n of heifers are transferred either for sale or to the beef herd for beef production.

Of the methods briefly mentioned above, the approach preferred is one where rather than actually specifying the number of replacements, constraints are included setting a maximum level, and the objective function is formulated in such a way as to calculate the optimal level of replacements.

So far, the elements which determine the number of animals in the national herd have been discussed. The next area for consideration therefore is the other element of supply, the output or in this context, milk yield.

2.3.3. Yield

One of the prime concerns for any producer, either agricultural or industrial, is to obtain the most from his available resources. The term 'most' does not necessarily apply solely to quantity - a farmer, for example, could decide to produce a quality product, at the expense of volume. Whether or not conscious of doing so, he would carry out some form of selection to improve his stock, or more importantly, the output from his stock.

One approach to determining annual improvement in yield is to calculate the genetic gain possible per year. Pearson and Freeman (1973) defined the rate of genetic progress, at the first calving, as being a function of the intensity and accuracy of selection on the females, and the life stage at which selection is practised.

The theoretical genetic gain per year can be calculated using the formula outlined below (Dalton, 1980):

$$\Delta G = \frac{h^2 \times i \times p}{GI}$$

Where ΔG = genetic gain per year;
h^2 = heritability;*
i = selection intensity;*
p = phenotypic standard deviation;
GI = generation interval*

The problem with this formula, however, is that it is not applicable to single sex traits (that is traits expressed in only one of the two parents, as is the case for milk). The formula for determining the genetic gain per year for single sex traits is as follows:

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*See glossary of terms

$$G = \frac{I_{BB} + I_{BC} + I_{CB} + I_{CC}}{L_{BB} + L_{BC} + L_{CB} + L_{CC}}$$

Where I = the genetic superiority of the parents over their own sex mean;

L = the generation intervals;

BB = bulls to breed bulls;

BC = bulls to breed cows;

CB = cows to breed bulls;

CC = cows to breed cows.

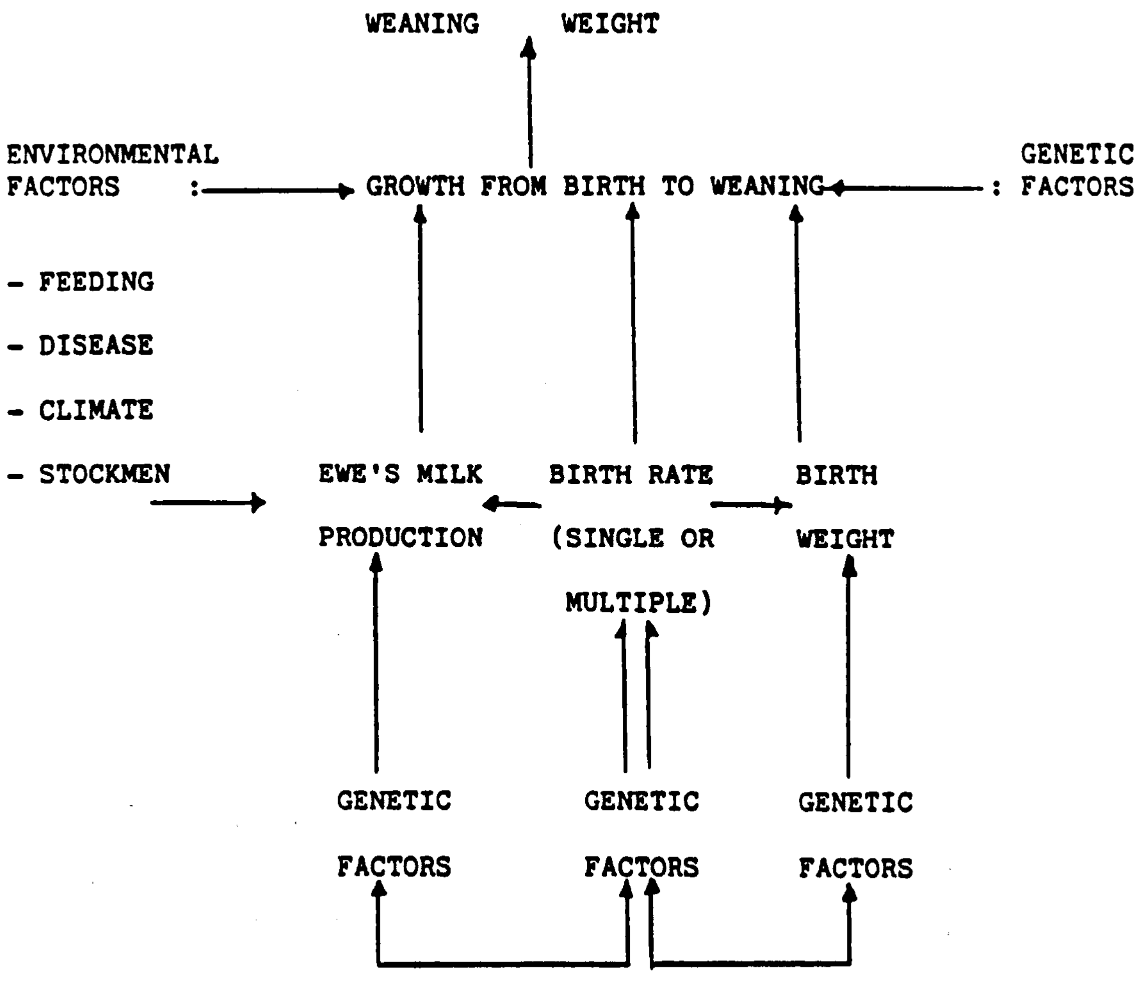
The nomenclature used in this formula was that used by Ploumi (1981); however, the formula is not original and is normally accredited to either Dickerson and Hazel (1944), or Robertson and Rendel (1950). An example of the application of this formula, along with an explanation of the genetic terms can be seen in Appendix (B).

The latter of the two above equations for calculating the annual level of genetic improvement differs in that, because of the nature of the traits to which it applies, it is necessary to consider the level of improvement that can be achieved at all stages of a selection programme. In a typical selection programme emphasis would be put on breeding both bulls and cows capable of producing offspring (of both sexes) with improved levels of the required trait(s).

The problem with using either of the above formulae for determining annual genetic improvement is that they fail to take into account environmental considerations which can influence improvement. An indication of the complexity of improvement can be obtained from figure 2.3 (Dalton, 1980).

Gartner (1981) calculated the yield of a cow, calving at a particular age using the following formula:

Figure 2.3 Factors influencing the weaning weight of lambs (Dalton, 1980)



$$Y_m = (G + E + \mu) \times (1 + 0.01m)$$

Where Y = yield;

μ = the mean yield of the heifer population corrected to the base age;

G = the genotype of the cow expressed as a deviation of μ ;

E = environmental factors of the cow expressed as a deviation of μ;

m = number of months since the base age of first calving.

This approach allows for the inclusion of environmental influences. The problem with this formula, for the context required, arises in obtaining reliable estimates of G and E for the dominant breeds in the United Kingdom. Another disadvantage with the above approach is that it is primarily concerned with calculating yield at a particular age - for the type of broad analysis being undertaken, age is not of prime concern.

In addition to the type of models mentioned above, there are several methods which have been used for estimating yield which do not make direct reference to genetic factors. The C.A.S. Report (1978) defined yield as being a function of the price received for milk and the price of concentrate feed.

Burger and Wijnands (1979) adopted a slightly different approach to that used by C.A.S. in that they defined the level of yield per cow as being a function of the total feeding units - both roughage and concentrates. This method has the advantage over that proposed by C.A.S in that it would allow fluctuation in yield, as a result of a change in the level of feeding,to be considered in the model. The problem with this approach, however, is obtaining reliable, representative data for all breeds, from which to determine the relationships.

This last approach is verging on some of the nutrition orientated models. As the concern of this thesis is primarily with the advantages of genetic diversity, nutritional models will not be discussed.

In contrast to the approaches already described for determining yield is the method adopted by Stewart, Burnside and Pfeiffer (1978), who used fixed increments for calculating annual improvement. Although this method has the advantage of being simple to apply, there are a few problems associated with its use.

One problem is choosing the initial year. It is necessary to look at yields for years either side of the chosen starting point to ensure that the base year is neither exceptionally high or low. The second problem concerns the increment or change in yield value used. Table 2.2 shows average yield figures for Friesian cattle in Scotland. Over the period 1969 to 1981, the average annual increase was 80.9 kg; for the period 1969 to 1976 the increase was 75.3 kg, whereas for the period 1974 to 1981 the figure was 92.1 kg.

Care must also be taken in that figures, such as those in Table 2.2, can be influenced by factors not mentioned. For instance, the average herd size in Scotland increased from 45 cows in 1965 to 85 in 1981 (S.M.M.B. 1981). In addition, during the period 1969 to 1981, various husbandry techniques changed. The level of concentrates fed in some herds increased from an average of 1683 kg/cow to 1783.3 kg (Personal communication B.O.C.M. Silcock). Also, during the later part of the period, the Friesian breed in the United Kingdom was being quite dramatically improved by the introduction of improved stock from Europe and Canada.

Table 2.2 Average yield figures for Friesian cattle in Scotland

Year	Yield (kgs)
1969	4416
1970	4429
1971	4475
1972	4663
1973	4702
1974	4742
1975	4854
1976	4943
1977	4939
1978	5226
1979	5254
1980	5287
1981	5387

(Source: Personal communication, SMMB)

The use of fixed increments can also be misleading in that it assumes that the annual improvement achieved to date will continue. Some geneticists will tend to question this, claiming that there is a limit to the level of improvement possible.

2.3.4. The objective function

Most of the basic principles of the objective function have already been discussed. What is of interest at this point is the criteria that have been used in modelling applications, and what costs and benefits should be considered. Prior to this, however, it is worth briefly reviewing the topic of from whose point of view is profit to be maximised or costs minimised. This question is discussed by Pearson and Miller (1981).

From the national viewpoint, when the market is in a state of equilibrium (supply equals demand), increases in income from production are worth relatively less than decreases in expenditure. The reason for this is that, being in equilibrium, there is no market for the additional output at the present market price. The effect, therefore, of an increase in production is to lower the prices and subsequently drive producers from the market, unless the increase is nullified by government action - for example, through intervention buying. An increase in production from the individual producers viewpoint, however, is more valuable than a decrease in expenditure provided he can continue to market all his products without reducing the price received.

The implication that can be derived from these comments therefore is that for an optimisation analysis carried out from the national viewpoint, greater emphasis should be given to cost reduction. The easiest way to achieve this would appear to be to use cost minimisation as the objective function.

The choice of which costs and income to include in the objective function is determined by the purpose of the model. Some authors believe that when dealing with a national project, particularly those financed to some extent by the government, costs and benefits included should also cover the social effects of the project, as well as physical inflows and outflows of capital (for example, Layard (1972) and Sugden and Williams (1978)). Difficulties arise however in quantifying some of the 'social' costs and benefits.

Hansen (1978) suggests that in a perfect market, analysis of projects along the lines of a commercial profitability study should be sufficient, and shadow prices would be the same as market prices. In the context of cost-benefit analysis studies, shadow prices are values which reflect the value to society of the resources used or the output produced (Little and Tipping (1972)). Hansen (1978) also suggests that the second round effects of a project should be considered in certain circumstances.

The first round effects of a project are those which can be directly attributed to it; second round effects are the "spin-offs" from a project. Hansen (1978) accepts that taking second round effects into consideration is not always feasible - at times it is difficult to identify all the direct effects - and subsequently should only really be considered if they could alter the ranking of projects in comparison studies.

Bearing in mind the comments and suggestions made by the advocates of cost-benefit analysis, it is interesting, and significant to note that all the agricultural modelling applications examined in the course of this research used either profit maximisation, or cost minimisation as a criterion. The costs and benefits used were actual values, which could suggest that determining some of the additional costs and benefits is not a straightforward matter. Sugden and Williams (1978) also suggest that at times the expense of determining these values is not worthwhile, and initial analysis using market prices is often sufficient.

2.4 Conclusion

In the course of this chapter, the major areas of concern to this project have been discussed. Not all areas have been mentioned however, for example, the adoption of a new or improved technology. Areas such as these will be discussed at the appropriate stages, and will include a brief review of the pertinent literature as an introduction.

The remainder of this thesis will focus upon the problem of designing and applying an approach to evaluating the economics of maintaining a store of genetic material for use in the United Kingdom dairy cattle herd.

CHAPTER 3 Possible approaches to calculating the economics of diversity

3.1 Introduction

The need for maintaining at least an element of diversity in some form in the domestic livestock populations has been the subject of a number of discussions (e.g. Bowman, (1974). As yet, however, few serious attempts have been made to quantify the costs and benefits involved with doing so.

The intention of this chapter is to consider various methods for evaluating the economics of diversity, prior to discussing the model applied in this analysis, which will be the subject of Chapter 4.

3.2 Theoretical approach

3.2.1. Three period methodology

When considering the economics of diversity, what is really being examined is whether or not it is worthwhile to increase the flexibility of a livestock population. It would be very unlikely that producers as a whole would alter their existing breeds in order to insure against a possible future event, unless either there was an economic incentive to do so at the time (such as subsidy or grant), or the need for, and benefits from, a change were visibly apparent. What this research is trying to determine therefore is whether or not some form of reserve could be established, which if and when a change occurs - requiring some alteration in the existing livestock population - would reduce the losses incurred by the industry as a whole.

One method would be to approach the problem as if it were a three period model - consisting of the present, the point in the future when the need for the diversity has arisen, and some point between the two.

There are 'S' possible futures states of the industry, each requiring alterations, to varying degrees, to the existing structure. For the sake of discussion at this stage, let it be assumed that all possible future states of the industry can be predicted, along with the likelihood of each state occurring.

Adopting some form of objective function - cost minimisation for example - we would wish to determine whether an interim structure, Y, exists such that :

$$\text{cost } (x \rightarrow y) + \sum_s P_s \text{ cost } (y \rightarrow Z_s) \leqslant \sum_s P_s \text{ cost } (x \rightarrow z_s)$$

where:

cost $(x \rightarrow y)$ is the cost of adjusting the current structure x to the interim structure y;

z_s is the optimal structure of the industry in state S;

P_s is the likelihood of the occurrence of state S.

In order to examine the feasibility of the above suggested approach, it is necessary to split the formula into three sections and examine what costs are involved in each stage.

3.2.1. **(a) Cost of adjusting from current to an interim structure**

In its simplest form this would amount to the costs involved with collecting, testing and storing germ plasm or maintaining small nucleus herds of animals.

Smith (1984a) estimated the costs involved with genetic conservation, a summary of which can be seen in Table 3.1 The values for maintaining a nucleus herd are for a single herd at a single location.

In its more complex and drastic form, the costs of adjusting from the existing to some interim structure could involve altering characteristics of the main commercial herd. Land (1981) suggests, for example, developing divergent strains which would increase the genetic flexibility of the herd and aid faster response to changes in the desired traits or characteristics. A counter proposal to this would be a central line.

In this instance the costs of adjusting would involve some sort of incentive to breeders and producers to change. The magnitude of the cost of these incentives would depend upon the degree of change necessary. Other costs could be the cost of operating slightly sub-optimal for a period, and would cover items such as temporary excesses or shortages of supply.

3.2.1. (b) Cost of adjusting from the interim to the final structure

The costs in this instance would depend primarily upon the time period from the identification of the final state to its occurrence. The magnitude of the costs would also be dependent upon the interim structure, and whether it involved stores of germ plasm or something along the lines of divergent strains, and the speed at which the necessary alterations could be effected. The principal costs would be those of either an excess or shortage of supply of the desired products for the market, and any longer lasting resulting factors such as permanent loss or reduction in market.

Table 3.1 Estimated cost of alternative methods of conservation

	Cattle	Sheep	Pigs	Chickens
		£		
Maintaining a breeding stock (per year)	5,000	3,000	12,000	3,000
Frozen semen	9,000	9,000	25,000	11,000
Annual storage	200	200	400	200
Frozen embryos (625 embryos)	75,000	50,000	— NOT POSSIBLE --	
Annual storage cost	500	500	--	--

(Source: Smith (1984a))

The cost of overproduction could be quantified as either the amount paid by the marketing bodies purchasing the surplus product(s), or if the excess could be channelled into the production of various dairy products, the costs would include those associated with storing surplus products. In this latter case, it may also be necessary, when quantifying the costs, to consider the consequences of the availability of additional dairy products on the market of substitute goods - such as margarine.

The cost of underproduction would depend upon whether an external supply existed for the desired product(s) at an acceptable price. Providing a suitable supply was available from foreign markets, the cost of underproduction would amount to the cost of the required imports. If no suitable external supply was available, costs would be harder to quantify in that consideration would have to be given to the consequences on the market size in the longer term. As a result of a long term shortage in supply, consumers would tend to either find substitute products, or adjust their pattern of consumption. The question in this case would therefore be whether, once the supply was available, the consumers could be tempted back. Attempts would also have to be made to quantify the cost of consumer dissatisfaction.

Quantifying the costs of either over- or underproduction for any of the meat producing sectors would require consideration of the interrelationships that exist between the various livestock sectors and their products.

The cost of adjusting from an interim to a final structure could also include some sort of incentive paid to producers. The incentive could be paid either to producers prior to the final state actually occurring, which would effectively reduce the period of misbalance between supply and demand once the state had occurred. Alternatively, the incentive could be paid once the state had occurred, to encourage a quicker transition to the required structure. In this latter instance, enouragement to change could also be effected by penalising producers for failing to produce in the desired fashion.

Another area of costs in this section could be those resulting from structural changes in the industry. This could include items such as additional cattle housing if the state S required more, lower yielding animals than present, or the more complex area of social costs arising from instances such as reducing the labour force required.

3.2.1. (c) Cost of adjusting direct to the future state

The costs in this section would probably be similar to those of going from an interim structure to the final state, but could be larger in that the time period necessary to change would (in all probability) be greater.

Complications arise with the above approach in that there is more than just one possible future state, which raises the question of whether it is in fact either feasible or economic sense for any interim structure to accommodate each possible state. In many respects it would be better to select the most likely states, and prepare for them. An alternative would be to consider all the possible states, and maintain an interim structure in some form, which would minimise the maximum possible loss or cost to the industry that could occur.

3.2.2. Cost/Benefit ratio approach

A cost/benefit ratio type of approach was suggested by Smith (1985). The analysis was applied to various livestock sectors in order to determine the number of different genetic lines or strains that should be kept to maximise the expected benefits from genetic improvement.

Benefits were defined as being the return in year one from one year of improvement, discounted over a period of years, minus the total costs.

Although this approach initially appears to be rather simplistic, it does provide fuel towards the argument in favour of maintaining diversity. Using the figures quoted in the article, the value of UK dairy production in 1980 was around £1,900m. The cost of one year's selection work estimated by Smith was just over £10,000. If one takes a more realistic value for annual genetic improvement of dairy cattle of 0.5%* and assuming that a 1% improvement in production results in a 1% improvement in value, the additional benefits from one year's work in 1980 could have been £9.5m. Even these very rough figures provide an indication of the scale of potential benefits from creating genetic diversity, particularly in relation to the comparatively low costs of storage.

An approach similar to that described above was actually applied in a report by the United States Department of Agriculture (USDA, 1976). Although not specifically aimed at arguing the case for conserving diverse genetic resources, it can be seen to add a certain amount of credence to the

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*O'Connor (1984) believes the actual genetic improvements achieved in the UK to be in the region of 0.7 to 0.8 per cent of the mean per year.

approach used by Smith. An example from the report can be seen below which quantifies the potential benefits of improving the current herd.

Potential benefit from reducing the loss in milk production due to mastitis

- production in 1973 was 115.6bn. lbs milk - an average of 9,967 lbs/cow;

- production requirements in 1985 estimated to be 120bn lbs of milk
- if current milk loss per cow of 5% reduced to 2%, production per cow would increase from 11,000 lbs to 11,347 llbs/cow;

- with output 11,347 lbs/cow require (120bn lbs + 11,347 lbs per cow) or 10.575m cows to achieve desired milk supply - 335,000 less than with current technology;

- Potential annual benefits = 335,000 x $650 (the cost of feeding and maintaining a cow for a year) = $217.8m.

3.3. Further broad considerations for any modelling approach

Perhaps one of the most crucial points that would need careful consideration in any analysis along the lines suggested above, is the time required by producers to effect the necessary changes if the need for diversity arose. In a perfect world, the industry as a whole would begin to prepare for the changes at least as the need became apparent. Unfortunately, this is not the perfect world.

It is a traditionally accepted view amongst many technological economists that the introduction of a new or improved technology follows an S-curve pattern, such as that in figure

3.1. Uptake of the new technology is initially slow, but then increases dramatically up to a certain level. Quantification of any such curve in relation to the introduction of different genetic material would have to be an approximation, although an analogy could be drawn from the introduction of breeds from Canada and Europe to the UK beef and dairy cattle herds. This subject will be discussed in more depth later in the thesis.

A further consideration in any evaluation of the need for diversity is by how much circumstances would have to change before producers would view altering their existing production profiles as being worthwhile.

3.4. Conclusion

The brief description provided of a three period model initially makes the approach sound plausible; however, problems would be encountered, not least of which being predicting every possible future state.

The question of whether or not resources should be allocated to maintaining a stock of genetic material could be argued by applying an approach along the lines suggested in 3.2.2. to current figures, concentrating primarily on characteristics which can be influenced by genetic manipulation. With regard to the dairy sector, the trait that usually springs to mind is lactation yield. Other possible, more interesting traits however are milk composition levels (the levels of butterfat and protein), the feed conversion efficiency and weight and quality of the calves. Table 3.2 shows a fairly basic calculation quantifying the potential benefits to producers from increasing the solids-not-fat* (SNF) content of milk by 1% from 8.8% to 8.9%.

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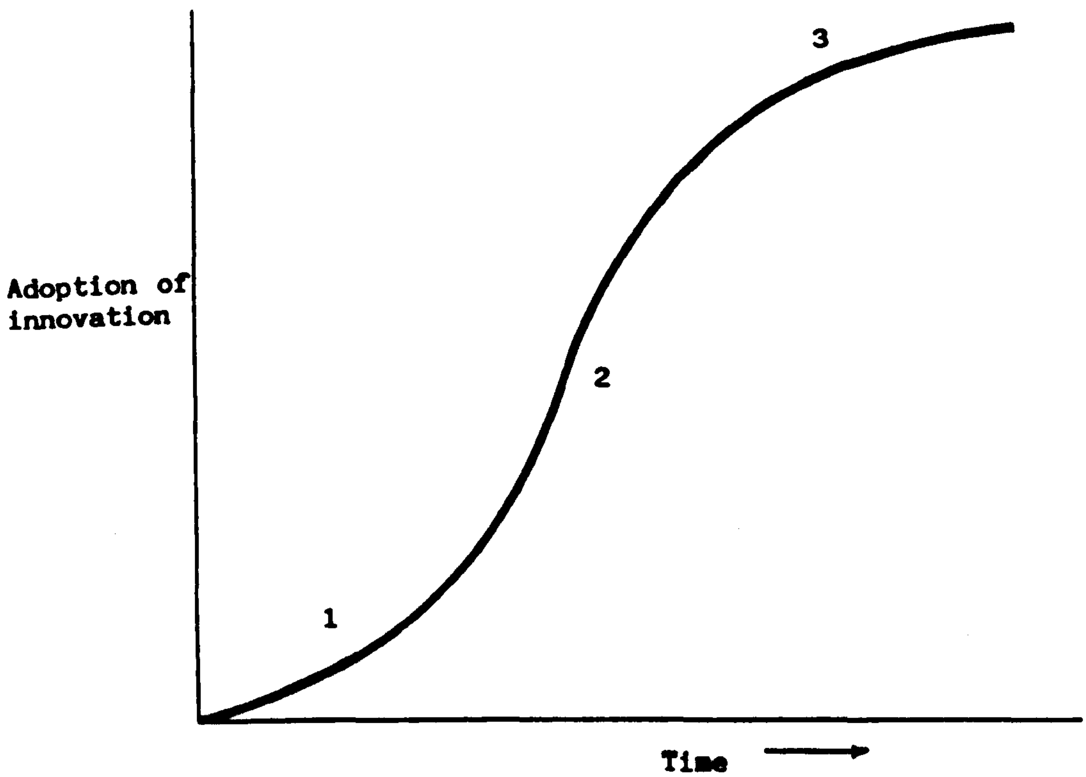
*Milk is basically made up of around 88% water, plus various solids which include butterfat, protein and lactose. SNF is the total of the solids - excluding fat and accounts for about 8.8% of the total weight.

Figure 3.2 An S-curve



1. Period of slow initial growth

2. Period of rapid, exponential growth

3. Period of growth slowing as the uptake of the innovation reaches some natural physical limit

Table 3.2. Calculations showing the potential benefits from increasing solids-not-fat content

Total volume UK milk production 1982	15,943 mn litres
Value of milk and milk products	£2,383 mn
Average yield/cow	5,500 kgs
Approx. solids-not-fat content	8.8% (484 kgs)

Potential benefits from increasing SNF weight by 1%

= result in SNF content of 8.9%, which would result in a supplement of 0.096p*/litre.

TOTAL NATIONAL BENEFIT OF £15.3m

(Sources: CSO Annual Abstract of Statistics, 1985, and MMB Diary Facts and Figures, 1983).

*The supplement refers to the additional payment given by the MMB for milk with SNF content higher than 8.8%

Similar calculations could also be done to demonstrate potential benefits of diverse genetic material, but this time from more of a nationwide view, rather than solely just dairy producers. Characteristics of interest from this viewpoint could be such that would reduce the current levels of surpluses of dairy products (in particular skimmed milk), or reduce the reliance on imported products. At present the UK imports both dairy products - being only around 70% self-sufficient in butter and cheese - and products such as soya meal for the manufacture of high protein cattle feeds. Calculation of the potential benefits from increasing UK self-sufficiency would need to include the consequences on the overall UK balance of trade picture.

It is not intended that this thesis should merely carry out repetitive calculations as a form of justification of the need for diversity. If one can work on the basis that there are potentially large benefits from having diversity, the attention will focus on the further question of in what form the diversity should be kept. Table 3.3 shows the theoretical value of a 1% improvement in volume for the main agricultural livestock products. The values are calculated on the assumption that a 1% improvement would not alter the value per thousand tonnes or per million litres. An increase of 1% for the meat producing sectors could be achieved either by increasing the number available for slaughter through increasing the progeny per breeding female per year, or increasing the average slaughter weight genetically. No account is taken in these figures of the additional inputs required to increase the level of output.

The discussion of how the diversity should be kept will try to examine whether it is more beneficial to increase the diversity of the existing dominant breeds by identifying and collecting genetically different strains, or whether breeds

Table 3.3 Value of a 1% improvement in the major UK livestock sectors

Total volume of milk sold	(mn litres)	15084	15943	16441
Value of milk and milk products	(£m)	2101	2383	2486
Value of 1% improvement	(£m)	17	16	21
Total no. cattle slaughtered	(000's)	4049	3629	3928
Value	(£m)	1600	1668	1831
Value of 1% improvement	(£m)	16	17	18
Total no. sheep slaughtered	(000's)	13978	13894	15068
Value	(£m)	465	517	562
Value of 1% improvement	(£m)	5	5	6
Total no. pigs slaughtered	(000's)	14845	15055	15989
Value	(£m)	862	925	911
Value of 1% improvement	(£m)	8	9	9

(Volume and product value figures from C.S.O. Annual Abstract of Statistics, 1985).

that currently have a lesser economic value should be kept. The basis for this evaluation will be a mathematical model, which will be the subject of the following chapter.

CHAPTER 4: Formulation of the Mathematical Model

4.1 Introduction

The prime purpose of this chapter is to look at the mathematical model that has been formulated to assist in determining the need for diversity. Initial discussion will be of a general format and involve examining the basic structure of the approach being applied. Later sections of this chapter will discuss the specific formulations that will be applied in the model. Results from the model will be the subject of discussion in the following chapters.

4.2 Methodology

One of the motivations for this research programme is the concern over how well, and at what costs, producers could alter the level and characteristics of supply if the main variables determining the type and volume of output have to change. The cause for this concern, particularly in the UK dairy herd, is that many livestock producers appear to be discarding breeds which are currently regarded as having a lesser economic value and replacing them with single purpose breeds from Europe and North America. The resulting narrow genetic base which is arising from these changes may be insufficient to meet possible changes in the pattern of demand or the economics of production.

The aim of the model is to create an approximate picture of a livestock sector as it is at present, and to determine the optimal method of fulfilling demand with the resources currently available. Evaluation at later stages will involve examining how best the current structure can be adapted to meet various possible changes.

The model has been constructed in such a way that the number of animals of each breed producing in any period is determined by the number of adult females in previous periods, the level of introduction of adolescent females entering the breeding herd and the proportion that are removed from production. For this analysis, the yield from each breed is assumed to increase over time as a result of improved stock entering the herd and better management and husbandry techniques.

As the concern of the analysis is with the best way for the industry to react given certain circumstances, the model has been formulated as an optimization type. The majority of the areas of interest within the model can be formulated as either linear, or linear approximations, which allows use of linear programming techniques. The implication from using linear approximations for certain relationships - such as yield - will be discussed at the appropriate stages.

Linear programming was also chosen because of its flexibility and ease of application to large modelling problems. Various approaches of dealing with risk and uncertainty were discussed in Chapter 2 - many of which involved assigning probabilities to the likelihood of certain outcomes. No such values are readily available for the situation being examined. A counter argument to this could be that subjective values could be assigned, or in the light of no information to the contrary, equal weightings could be given to the likelihood of each outcome.

The argument against adopting such an approach partly goes back to the reason for deciding on using linear programming (aside from its applicability) - namely its flexibility and ease of use. Further, it is by no means clear that the additional problems associated with assigning probabilities to outcomes would be rewarded with better quality results for this analysis.

What we wish to determine in the initial stages of the evaluation is by how much the key variables have to change before the existing structure or combination of breeds is no longer the best available. The variables that are of main interest are the costs of production, the contribution towards total supply received from each animal (yield), and the level and characteristics of demand.

The easiest way of achieving this analysis, considering the formulation of the model, is to apply parametric programming techniques.

In determining the sensitivity of the current structure of the national herd in the above fashion, it is possible to discover the variables which have most influence on producers, and highlight the areas where it would require changes of unrealistic proportions before the structure would alter.

The next stage of the analysis is to draw up a list of possible occurrences which could result in the current structure requiring to be altered, and for each, determine the theoretical optimal structure. Results obtained at this stage can then be compared with the costs and benefits associated with achieving the necessary adjustments by genetically improving the existing dominant breed(s).

The model has not been designed to calculate the benefits of having diversity, but merely to highlight whether or not a need for it exists in the form of identifiably different breeds and strains. The costs and benefits of having diversity available will depend on the circumstances involved, and, as a result, each situation should be discussed in a manner that is not strictly controlled by the framework of a simplified mathematical model.

4.3 Model construction

4.3.1. Introduction

As already stated, the concern of the model is with the effects of changes of the main determining variables on the level and characteristics of supply. Ritson (1979) stated that the quantity of an agricultural product supplied to a market per time period, Q_s, can be expressed as a function of seven key variables.

$$Qs = F(T, P_p, P_1 \ldots n, I_I \ldots m, O, N, R) \qquad \text{Eq. 4.1}$$

Where:

T	=	the production function of the product or the technological conditions of production;
P_p	=	price of the product;
$P_1 \ldots n$	=	prices of n other products;
$I_1 \ldots m$	=	prices of m inputs;
O	=	objectives of the farm firms;
N	=	number of firms supplying the market;
R	=	structure of the agricultural industry.

Although this formulation is comprehensive, it does not fulfill the requirements of this analysis. Of prime interest with regard to supply is the events that could require a change in the current breeds. In order to achieve this objective the assumption that the level of supply is controlled by demand has been adopted. The decision of how the required level of demand is met is influenced by a combination of economic considerations and physical constraints. For the purposes of the evaluation in this instance, the level of demand will be specified outside the model.

With these considerations in mind, it is possible to adjust the relationship stated in equation 4.1, giving the basis of the supply function that will be used in the model.

$$Q_s \geqslant Qd \qquad \text{Eq. 4.2}$$

$$Q_s = g(P, Y, C, O)$$

$$\text{Eq. 4.3}$$

$$R = h(P, Y, C, O)$$

Where:

Qd	=	quantity demanded by the market;
P	=	number of animals in the national herd or flock involved with production;
Y	=	output or yield from each animal;
C	=	costs associated with production;
O	=	objectives of producers;
R	=	the structure of the particular agricultural sector.

Each of the above variables will be discussed in some detail, outlining how they will be calculated and their significance in the model structure. Prior to this however, it is pertinent to mention a detail about both supply and demand that has not been discussed.

It is not really sufficient to say that the total demand for pork, for example, is x thousand tonnes; the figure can be broken down into various amounts for the products required - bacon, ham, joints etc. For the purposes of this evaluation, therefore, both supply and demand will be treated as vectors (one dimensional arrays) - demand being a vector of the total requirements for each product or characteristic, and supply being the amounts of each particular product supplied per animal, multiplied by the total number of animals producing.

4.3.2. The number of animals involved with production

Various relationships for calculating the size of a national herd have been suggested in a number of articles - Tryfos (1974), for example, defined the total number in a herd as being a function of the sale price per animal and an index of livestock feed prices. Of more concern than purely total numbers, however, is the total number involved with production. For the meat producing sectors, the number producing is the number available for slaughter, whereas for the dairy sector, interest is in the number of female cows and heifers in milk.

For the purpose of this evaluation, prime interest is with how the numbers of each breed change from period to period. If demand changes, or factors influencing the economies of supply alter, one of the options available to producers is to alter the total number producing (the other alternative being to alter the level or characteristics of output). Any decision to alter the numbers producing has to be constrained by biological factors, and influenced by economic considerations. Equation 4.4 identifies the basic general relationship involved with calculating numbers involved with production.

$$N\ (B,\ T) = f_1\ (A\ (B,\ T - n),\ W\ (B,\ T)) \qquad \text{Eq. 4.4}$$

Where:

$N\ (B,\ T)$ = the total number of breed or strain B involved with production in period T;

$A\ (B,\ T-n)$ = the number of adult females of breed B n periods earlier;

$W\ (B,\ T)$ = withdrawals.

In the above general formulation, the number of periods earlier, n, will depend upon a combination of the length of each period, and the generation interval and the type of sector being examined (i.e. meat or milk producing). The formulation in equation 4.4 can be expressed more specifically with regard to the dairy sector, as demonstrated in equation 4.5. As a result of being more sector specific, the precise variables involved differ slightly from those used above. The difference, however, is very slight as will become apparent in due course.

$$N\ (B,\ T) = N\ (B,\ T - 1) + I\ (B,\ T) - W\ (B,\ T) \qquad \text{Eq. 4.5}$$

Where:

$N\ (B,\ T - 1)$ = the number producing in the previous period;

$I\ (B,\ T)$ = introductions to the herd.

4.3.2. (i) Withdrawals

Withdrawals amount to the animals that for some reason are no longer involved with production, and can be classed as one of three categories:

(i) deaths;
(ii) involuntary removals;
(iii) voluntary removals.

The first category is self-explanatory. Involuntary removals account for removals from the production herd due to disease or serious injury. The level of involuntary removals and deaths is usually regarded as being a function of the average age of the animals in the herd, and the standard of management and husbandry.

In the analysis that is to be applied, it would be infeasible to take into consideration all these factors when determining the level of involuntary removals.

Voluntary removals are determined by factors such as the age of the animals, the price they would realise at sale now, the costs of feed and labour and their potential production value. Their potential production value can be the animal's value if kept for a further year before being sold, or its value as a member of the adult breeding herd.

In the meat producing sectors, voluntary removals correspond to the variable P mentioned in equation 4.3.

4.3.2. (ii) Introductions

The total number of animals entering the production herd in any period is controlled by a combination of the number of breeding females in the herd at some point earlier in time, and litter size. Numbers are also influenced by survival rates.

At the individual producer level, the number of introductions is determined by a selection of factors - probably the most influential being finance. The number of introductions to the national herd, however, is influenced by demand and the economics of production.

4.3.3 Yield or output

Various relationships have been proposed for calculating yield; the majority of articles, however, have dealt with the question of average milk yield per dairy cow (for example, Gartner (1981), and C.A.S. (1978)). The decision of which formulation to employ would depend upon the required circumstances. It would seem acceptable, at this stage, to suggest that the level of output is a function of the breed, the level of inputs in the form of feed, and the age of the animal.

If a change in the style or level of production was deemed necessary, one of the options available to producers would be to alter output through genetic improvement. Taking this into account, yield could be expressed in the following form:

$$Y(B, T) = f_2(B, F, Y(B, T-1), \Delta G) \qquad \text{Eq. 4.6}$$

Where:

Y (B, T)	=	yield of breed B in time T;
Y (B, T-1)	=	yield in the previous period;
F	=	feed input;
Δ G	=	genetic improvement - this could include both genetic drift and any conscious genetic improvements.

4.3.4. Objectives of producers

The term 'objectives of producers' is probably best defined by making reference to Ritson (1977) who described the objectives as being the criteria which, for a given technological and price environment, motivates the farm firm in coming to a decision on what to produce, how much to produce and in what way to produce it. Concern in this instance, however, is what influences the dairy industry as a whole in its choice of breeds which together make up the national herd.

There is a range of criteria that could be applied. Probably the most commonly applied objective function is profit maximisation/cost minimisation. Understandably, this assumption has its critics. Lin, Dean and Moore (1974) for instance questioned the applicability of profit maximisation in the context of determining optimal courses of action in agricultural production, favouring utility maximisation.

The question of utility versus profit maximisation leads onto the problem of determining what costs and prices should be used in the evaluation. Sugden and Williams (1978) point out that if there is something constraining the market in some way, market prices will not in fact reflect the true equilibrium price. In such circumstances, they suggest alternative values should be sought.

Despite these criticisms, it is recognised as being reasonably acceptable to use market prices and a profit maximisation/cost minimisation type of objective function - providing any limitations from doing so are made apparent.

So far, three of the four elements which determine the level and characteristics of supply (mentioned in equation 4.3) have been discussed. In order to discuss to any extent the costs of production it would be necessary to make direct reference to a specific livestock sector. Costs will therefore be discussed in greater detail later on in this chapter.

4.3.5. Conclusion to the general format

The model has so far been discussed in fairly general terms, with reference being made to the basic principle that is to be applied. The basic concept of this evaluation is that the level of supply is controlled by demand, whereas the means of achieving the required level is determined by a mixture of economic and biological factors.

The structure of the model outlined will now be discussed in more detail by making specific reference to the UK dairy cattle sector. The model will be constructed in such a way as to allow the theoretical optimal mix of breeds to be determined, and also how producers should react, as a whole, over a number of time periods for given changes.

4.4 The UK dairy cattle sector

4.4.1. Introduction

The UK dairy herd currently consists of four or five major breeds - Friesian, Holstein, Ayrshire, Jersey and Guernsey. Alternatively it could be said that there are three main breed groups:

- the black and white breeds (Friesian and Holstein) which are high volume yielding breeds, producing milk with a comparatively low fat and protein content.
- The Channel Island breeds (Jerseys and Guernseys) which are low volume yielding breeds, but producing milk with a high fat and protein content.
- Breeds such as the Ayrshire and Dairy Shorthorn which were at one time popular, but have been losing ground to the black and whites. Milk output is lower than the black and white breeds, but with a higher fat content.

Recent trends have resulted in Friesian and Holstein numbers accounting for almost 90% of the total herd, with Channel Island breeds amounting to around 4%. If one looks at how the numbers of each breed have been changing, the implication is that, unless something occurs, within a decade the UK herd will consist almost entirely of Holstein and Freisians.

A further reason for examining the need for diversity with regard to the dairy cattle sector aside from a simple concern about the declining numbers of some breeds, relates to our membership of the European Economic Community. Since this research project started, legislation has been passed by the EEC requiring the U.K. to allow the import of liquid milk for human consumption. Changes have also been introduced to try to reduce the EEC surplus of dairy products - the changes amount to a quota system, penalising a country for over-production. This directly affects countries like the UK and the Netherlands where the average yield of dairy cows is comparatively high (see Table 4.1). Suggestions are, therefore, that the UK producers may be forced to change their current patterns of production, to fit more into line with EEC agricultural policy.

Prior to the detailed description of the dairy model it is interesting to note the system that will be defined in algebraic terms. Figure 4.1 defines the system, and the system boundary. The prime interest, as has been stated, is how breeders alter the herd structure under certain conditions - the major influencing factors being demand, and the economics of production.

Changes from one breed to another will have some knock-on effects outside the immediate system boundary, affecting the supply of beef, which in turn has implications on the sales of pork and lamb (assuming a free market). Factors such as this can not be considered fully in the model - account will be taken and included in the discussion about the different possible strategies.

4.4.2.1 Supply

For the purposes of the analysis of the UK dairy cattle sector, the characteristics of interest are liquid volume, butterfat and protein. The justification for using these traits is the CAS Report (1978) on the UK dairy cattle sector. Any characteristic or trait that can be identified, and to which a value can be assigned could be used in the approach.

Table 4.1 Annual average milk yield per dairy cow

Country	1981 (litres)
Belgium	3807
Denmark	4731
France	3574
Germany	4409
Irish Republic	3219
Italy	3251
Luxembourg	3900
Netherlands	4958
United Kingdom	4766

(Source : EEC Dairy Facts and Figures, MMB)

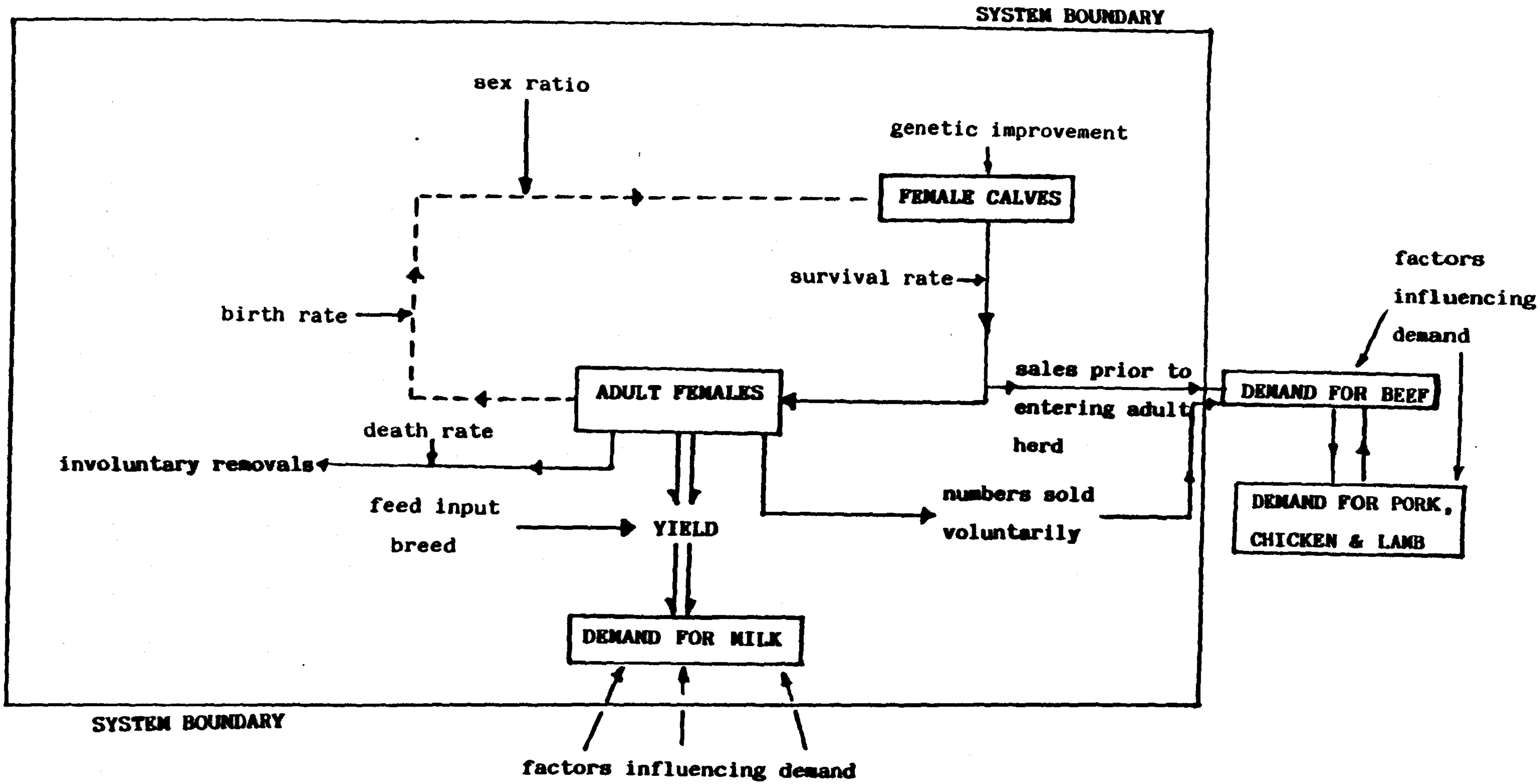


Figure 4.1 System diagram of the milk producing sector

As already stated, the basic assumption of the model is:

$$TS \geqslant TD \qquad \text{Eq 4.7}$$

Where:

TS = vector of total supply;

TD = vector of total demand.

Total supply could be taken to include imports, whereas total demand could include products for export.

Having already mentioned the production characteristics of interest, equation 4.7 can be expressed in a more complete form.

$$\begin{aligned} &\sum [LM\ (B,\ T) \times N\ (B,\ T)] \pm \delta_1 = TDM \\ &\sum [SF\ (B,\ T) \times N\ (B,\ T)] \pm \delta_2 = TDF \qquad \text{Eq 4.8} \\ &\sum [SP\ (B,\ T) \times N\ (B,T)\ ] \pm \delta_3 = TDP \end{aligned}$$

Where:

N(B,T)	=	average number of breed B producing in period T;
LM(B,T)	=	average milk yield (expressed in litres);
SF(B,T)	=	average fat yield (kgs);
SP(B,T)	=	average protein yield (kgs);
TDM	=	total demand for liquid milk;
TDF	=	total demand for fat;
TDP	=	total demand for protein;
$\delta_1 \delta_2 \delta_3$	=	balance between supply and demand.

It is not sufficient to express the above equation as inequalities, hence the inclusion of the balance variables. If for any reason, supply and demand are not level, costs will be incurred for both under- and over-production. Including the three variables allows provision for such costs to be considered in determining the optimal structures.

Until recently, δ_1, the balance between the supply and demand for liquid, could only have been a negative value, representing a surplus of production. Recent EEC ruling however, has resulted in the UK now having to allow the import of liquid for human consumption.

Levels for each of the balance values will be determined in the model by the levels of supply and demand. It may be necessary to impose bounds under certain circumstances.

4.4.2.2 The number producing - N(B, T)

One of the prime concerns of the model is how producers would alter their combination of breeds or strains, over time, given certain changes. The formulation applied, therefore, has to be suitable to allow the analysis to cover more than a single period.

The CAS Report (1978) took the above suggestion a stage further, by splitting supply down to output from different breeds, in separate geographic regions for each period. To apply such a format would require substantial amounts of detailed data, which does not appear to exist. (The Milk Marketing Boards report production information on different breeds, and for different regions, but not for the different breeds in each region).

As defined in equation 4.5, the number producing is determined by the number of adult cows producing during the previous period, plus any introductions, less withdrawals. It is pertinent therefore to look at the formulations for introductions and withdrawals.

4.4.2.2 (i) The number of introductions to the herd - I(B,T)

CAS (1978) defined the number of heifers introduced to the herd as being a function of the producer prices for milk, and the price of cattle feed. McFarquhar and Evans (1971) adopted a more complex approach, defining the number of replacement heifers as being a function of:

- the average guaranteed price for milk in the current and previous period;
- the average guaranteed price for clean fat cattle during the same period;
- the average price of compound cattle feeds 6 months and 18 months prior;
- the amount of hill cow subsidy in the current and previous period.

The formulation that is to be applied in this context is that the level of introductions as such, will not be defined, but constrained by the number of female calves born two and three periods previously. This approach works on the assumption that the average age of animals entering the adult herd is 30 months.

$$I(B,T) = 0.5\,\alpha_1 (F(B,T-3) + F(B,T-2)) - M(B,T) \quad \text{Eq. } 4.9$$

Where:

I(B,T) = number introduced;

F(B,T) = number of female calves born in period T;

M(B,T) = number of female calves sold out of the national dairy herd;

α_1 = percentage of calves which survive from birth to 30 months.

Including the variable M(B,T) permits the constraint to be formulated as an equality allowing consideration to be taken in the objective function of heifers of any breed not required in the adult herd.

Applying equation 4.9 in the evaluation will require the variable F(B,T) to be defined.

$$F(B,T) = 0.5\alpha_4 \quad (0.25\ N(B,T) + 0.75\ N(B,T-1)) \quad \text{Eq. 4.10}$$

Where:

N(B,T) = number of adult females producing;

α_4 = calving mortality (expressed as a percentage).

The assumption made in the above format is that the gestation period is nine months, and that 25% of calvings occur in the first quarter of each year (see Table 4.2). The assumption of a male:female sex ratio of 50:50 is used.

This format does not allow for producers to crossbreed - either with a beef or a different dairy breed sire. To include provision for dairy crosses would require each cross to be treated as a new breed. The results from crossing dairy breeds would only increase introductions for the required breed after four generations of back-crossing.

As the formulations being used are either linear or linear approximations, there would be little benefit obtained from the model by including the provision for dairy crosses. The main effect of interest to this analysis which would arise from considering dairy crosses would be on the substitution time i.e. the time it would take to move from one breed mix to another. This will be examined outwith the model, and included in the comparison of strategies.

Table 4.2 Heifers and cows calving each month 1980–81

Month of calving	Total calvings	%
April	176.6	6.48
May	135.5	4.97
June	106.3	3.90
July	137.8	5.06
August	228.8	8.40
September	356.5	13.09
October	335.6	12.32
November	305.4	11.21
December	247.8	9.10
January	242.9	8.92
February	229.4	8.42
March	220.0	8.08
TOTAL	2722.8	100.0

	% of total
1st quarter	25.42
2nd quarter	15.35
3rd quarter	26.55
4th quarter	32.63

(Source : M.M.B. Dairy Cost Survey)

Allowing producers to cross with beef sires will be included in the model. It will be assumed that the progeny from the beef cross will be transferred from the dairy to the beef herd.

$$F(B,T) = 0.5\, \alpha_4 (0.25\, N(B,T) + 0.75\, N(B,T-1)) - BX\, (B,T) \qquad \text{Eq. 4.11}$$

Where:

BX (B,T) = the number of female calves born which are the progeny of a beef sire.

4.4.2.2 (ii) Withdrawals - W(B,T)

Withdrawals can be split into three categories - deaths, involuntary and voluntary removals, each of which is dependent upon a number of factors - some of which are outside the immediate system boundary.

From current literature there appears to be three methods for tackling the problem of quantifying withdrawals:

- (i) adopt a 'cut off' age, where it is assumed that, on average, cows are kept only for a certain number of years;
- (ii) a percentage of the herd are culled each period;
- (iii) calculate disposals each period taking into consideration factors such as the health status of the herd, fluctuations in the milk and beef markets, and the demand for breeding stock (Asdell, 1951).

CAS (1978) employed the first of the above approaches, calculating the number culled as being equal to the number of heifers which entered the herd 5 years earlier. (Young, Lee and Waddington (1980) calculated the average life of a dairy cow in the adult herd as being 3½ years).

The method that is to be used in this instance is for deaths and involuntary removals to be calculated as a fixed percentage of the total number in the herd in the previous period.

Figures for determining the percentage of animals removed from the adult herd could be derived from values obtained by the Milk Marketing Board (MMB) and Beynon (1978). Table 4.3 shows the results from the MMB National Milk Records surveys for 1973-74 and 1976-77. The figures show the production 'status' (ie the proportion still producing or dead etc) of the cows involved in the survey for the two years. Table 4.4 is the result from the survey carried out by Beynon (1978) showing the destination of the animals classed as sold in the MMB survey.

Unfortunately, it is debatable as to whether the figures shown for the two years are directly comparable, because of the bad drought in the summer of 1976. A comparison between the figures in Table 4.3 shows that the percentage died and sold in 1976-77 was higher than for 1973-74.

Levels of voluntary removals will not be defined in the model, allowing the numbers to be determined by the demand for milk, fat and protein, and the comparative economics of production for each breed. In order to prevent the model from recommending no voluntary removals for particular breeds, a lower bound will be imposed, stating that voluntary withdrawals have to be greater than a certain percentage.

Table 4.3 Results from MMB National Milk Records Surveys

	Dead	Sold[1]	Dry[2]	IX[3]	LP[4]	Calved in milk[5]	Ceased Recording
				%			
				1973-74			
Friesian	0.4	9.8	34.2	7.0	47.8	0.3	0.6
Ayrshire	0.5	10.2	40.5	6.6	41.6	0.2	0.4
Jersey	0.7	10.9	33.7	7.2	46.7	0.3	0.4
Holstein	———— No Figures Available ————						
				1976-77			
Friesian	0.4	13.0	33.2	5.6	47.4	0.2	0.2
Ayrshire	0.6	15.8	36.2	4.4	42.8	0.1	0.1
Jersey	0.9	15.6	33.5	5.1	44.6	0.1	0.1
Holstein	0.5	9.1	29.8	3.2	57.3	0.2	---

Notes:

1. The term 'Sold' does not necessarily mean sold from the dairy herd - it also covers animals sold by dairy farmers to other dairy producers.

2. Dry before completing a 305 day lactation.

3. IX - down to one milking per day by the 305th day.

4. LP - complete a 305 day lactation.

5. 'Calved in milk' means they calved prior to completing a 305 day lactation.

(Source : Breeding and Production, Vol. 25, 1974-75, and Vol. 28, 1977-78, MMB)

Table 4.4 Destinations of cows sold in the national dairy herd

Destination	1972-73 Number ('000)	1972-73 Percent	1976-77 Number ('000)	1976-77 Percent
Further milk production	49	9.8	28	4.8
Slaughter for beef	384	77.2	498	83.9
"Knackers/kennels"	44	8.8	47	8.0
Transfers out	16	3.2	15	2.6
Not known	5	1.0	4	0.7
TOTAL DISPOSALS	**497**	**100.0**	**593**	**100.0**
TOTAL COWS IN ENGLAND AND WALES	**2859**	—	**2709**	—

(Source : Beynon, (1978))

Having discussed the formulation for determining the numbers of each breed producing in each period, the next stage is to look at the other part of the supply function - the average yield per animal.

4.4.2.3 Yield

In the description of the general format of the model, it was stated that yield is a function of feed inputs, yield in the previous period, breed and any genetic improvement (equation 4.6). For the dairy herd, yield can also be influenced by environmental factors.

The aspects of yield that are of interest in demonstrating the model are liquid volume and fat and protein content. Initially methods for calculating liquid volume will be discussed.

4.4.2.3 (i) Liquid milk volume

The need for calculating yield really arises more in the second stage of the evaluation process, where the interest is in how the national herd structure changes over time.

From an examination of the literature, it would appear that there are at least four alternative methods of calculating milk yields:

- (i) using fixed increments;
- (ii) calculate yield taking into consideration factors such as environmental influences, age and the genotypic deviation of the cow from the mean yield of the population (Gartner, (1981);
- (iii) define yield as a function of the producer receipts for milk, and the price of concentrate feeds (CAS, (1978);

(iv) calculate yield as purely a function of concentrate inputs (Gordon, (1983).

In many respects, the method used is dependent upon what one hopes to achieve from the model. The method used by the MMB for short term forecasting is that current trends are extrapolated on a straight line basis. Factors are then examined which would cause the estimated figures to differ. Consideration is given to things such as changes in the average herd size (see Table 4.5), and milking practices.

Probably the ideal method would be along the lines proposed by Gordon (1983), which calculates yield as a function of feed inputs. Problems arise, however, in that there is very little data available from commercial herds for different breeds.

Of the methods suggested for calculating yields, there is information to calculate annual fixed increments. Despite being criticised for its simplistic approach, this method can be used (with care) if one adopts the assumption that current feeding practices (levels of concentrates and bulk used) will not change.

Results from a regression analysis on yields for the four main breeds that will be used in the analysis can be seen in Table 4.6.

4.4.2.3 (ii) Fats and protein yield

The method for calculating fat and protein yield is not necessarily dependent upon the method used for calculating liquid yield. For the purposes required in this instance, however, fat and protein will be determined as a linear function of milk yield.

Table 4.5 Results from MMB survey showing yields for different sizes of Friesian herds

1980 / 81

Average herd size (cows)	31.54	70.89	146.81
Total milk yield/cow (litres)	4459	5154	5567

(Source : MMB Economics Division)

Table 4.6 **Analysis of yields for different breeds**

	Friesian	Ayrshire	Jersey	Holstein
		(litres)		
1970	4,445	4,042	3,207	4,823
1971	4,560	4,139	3,244	5,113
1972	4,631	4,197	3,308	5,219
1973	4,666	4,236	3,336	5,301
1974	4,624	4,193	3,281	5,320
1975	4,720	4,285	3,338	5,460
1976	4,858	4,382	3,410	5,663
1977	4,971	4,456	3,470	5,772
1978	5,232	4,668	3,623	6,001
1979	5,303	4,741	3,675	6,042
1980	5,384	4,805	3,719	6,067

(Source: MMB)

Friesian:

$Yield_t$ = 5,323 + 93.7t (10.33, 10, 0.914)

Ayrshire:

$Yield_t$ = 4,753 + 75.2t (10.71, 10, 0.919)

Jersey:

$Yield_t$ = 3,675 + 51.1t (8.93, 10, 0.887)

Holstein:

$Yield_t$ = 6,143 + 123t (17.88, 10, 0.97)

t = time, 1980 = 0, 1981 = 1 etc.

figures in brackets = (T coefficient, degrees of freedom, R^2).

The problem with calculating yields for fat and protein using any approach relates to the lack of available information. Figures for protein content are only available from 1977 - prior to this, interest was with solids-not-fat (SNF). Values for fat and protein in the analysis will be expressed as weights (kgs), whereas liquid yield will be in litres. The results from the regression analysis for fat and protein yields can be seen in Table 4.7.

In the preceding sections of this chapter the formulation of the main components of the model have been discussed. It is now necessary to focus attention on the objective function and its components.

4.4.3 The objective function

In the evaluation of the economics of maintaining diversity the model has two main uses - firstly to examine the sensitivity of the existing national herd structure, and secondly, to determine the optimal structures for certain changes. The basis upon which any evaluation will be carried out is cost minimisation.

Determining the optimal strutures for different scenarios can be split into two categories - the theoretical optimal, regardless of the current structure of the national herd, and the realistic optimal. This latter category would include costs associated with adjusting the current breed structure as well as imposing starting values for the number of each breed.

There are three main cost areas necessary for the analysis mentioned.

Table 4.7 Analysis of fat and protein yield

(Using the general format, $Yield_t$ = C + M (LM(B,T)) where C and M are constants and LM(B,T) is liquid yield.)

	Fat		Protein	
	C	M	C	M
Friesian	-39.3	0.0462	-28.2	0.0389
	(70.98, 10, 0.998)		(96.82, 3, 1.00)	
Ayrshire	-27.0	0.0459	-38.6	0.0428
	(52.38, 10, 0.996)		(84.69, 3, 1.00)	
Jersey	-72.3	0.0722	-16.5	0.044
	(32.25, 10, 0.990)		(50.10, 3, 0.999)	
Holstein	-13.8	0.0407	-79.-	0.0459
	(34.44, 10, 0.920)		(20.09, 3, 0.993)	

Figures in brackets (T coefficients, degrees of freedom, R^2)

(i) the costs of milk production;

(ii) the costs associated with altering the structure of the national herd;

and (iii) the costs of an imbalance in supply and demand.

Each area will be discussed separately, examining the formulation being used.

4.4.3. (i) The costs of milk production

As with other areas, there is limited information available relating to production costs for different breeds. Cost information is available from three sources - the Milk Marketing Boards, cattle feed manufacturers and the various breed societies. Information from some of the breed societies is unfortunately of little value, tending to refer to the better producing animals, and be based on small sample sizes. Of the remaining two sources information is available for different yield groups, but only the MMB publish figures relating to specific breeds. Unfortunately it would also appear that the feed company's information is not totally representational of the national average (see Table 4.8). To add to these problems, specific breed costings are only available for 1980/81 from the MMB.

The method proposed for obtaining cost values which can be used over a number of time periods is to examine generalised cost information to determine any underlying trend. The results from this analysis will then be applied to estimate costs of production for each breed. Values will be arrived at by the following method:

- the linear function derived for calculating the change in purchased feed prices is -

Table 4.8 A comparison of MMB and feed manufacturers information

	Milk Marketing Board (1980/81)		Feed Manufacturer (1980)
Average herd size (cows)	62.02		99.37
Average yield per cow (litres)	5107		5621
		£	
Value of milk sold per cow	651.2		738.5
Variable costs per cow	299.3		339.0
Gross margin per cow	351.8		399.4
Gross margin per hectare	679.2		855.0

(Sources : MMB Milk Costs 1980/81 Working Tables, BOCM Silcock - Dairy Costings 1980)

$$price = (6.374 \times t) + 230.34$$

Where t = time (1980/81 = 0) (see Table 4.9), therefore in 1980/81, the average price for purchased feed is £230.34 per cow;

- in 1980/81, an average of £204.43 per cow was spent on purchased feeds by Friesian producers (see Table 4.10);

- assuming that any underlying circumstances do not alter, values for the cost of purchased feed used by Friesian producers can be calculated in other periods by multiplying the value obtained from the linear function by 204.43/230.34.

The cost values being used for determining the trends are deflated, using the Index of Total Domestic Expenditure* as the deflator.

It is arguable whether linear relationships are appropriate for the costs of production. Some of the information available relating primarily to Friesians would appear to suggest that the costs of milk production would be represented better by a step function. Costs are very dependent upon herd size, which is a factor not being considered in this analysis. For the purposes of this evaluation, it will be assumed that the individual herd size for each breed stays constant. The analysis carried out on the available figures did not indicate that a non linear relationship would be more appropriate.

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*Total Domestic Expenditure was used in preference to other indicators in that it reflects price movements in a broader mix of products than the usual measure of inflation - the Retail Price Index - and is not influenced by interest rate movements as other indices.

Table 4.9 Deflated production costs, and the resulting linear functions

	Index of Total Domestic Expenditure	Purchased Feed	Home Grown	Grazing	TOTAL FEED COSTS	Labour Costs	Misc. Costs	GROSS COSTS
				(£ per cow)				
1965–66	21.2	155.94	75.94	46.18	278.07	120.42	101.18	499.67
1968–69	23.8	152.18	60.92	45.00	258.11	107.60	108.19	473.89
1971–72	29.3	145.05	60.41	42.79	248.26	103.45	110.95	462.66
1972–73	31.6	151.80	61.39	46.86	260.06	107.12	117.94	485.12
1973–74	34.6	185.81	76.79	50.37	312.97	120.69	116.24	549.90
1974–75	41.3	188.16	81.65	53.07	322.88	110.19	118.81	551.88
1975–76	51.6	182.55	94.91	54.46	331.93	111.42	121.77	565.12
1976–77	59.6	261.91	85.75	53.44	401.11	103.96	125.35	630.42
1977–78	67.5	215.70	78.69	57.37	351.76	97.09	126.72	575.57
1978–79	74.1	229.42	90.42	45.88	365.72	98.51	112.01	576.24
1979–80	84.4	234.59	90.05	45.02	369.67	100.71	113.74	584.12
1980–81	100.0	202.00	87.00	43.00	332.00	103.00	114.00	549.00

Using the linear format y = mt + c (t = time, 1980/81 = 0)

y	m	c	R^2 %	T
Purchased feed	6.374	230.34	53.5	3.70
Home grown feed	1.832	89.65	40.6	2.92
Grazing costs	0.189	49.75	0.0	0.56
Total feed costs	8.390	369.74	54.2	3.74
Labour costs	-1.12	100.29	37.4	2.75
Miscellaneous costs	0.939	121.21	27.4	2.27
GROSS COSTS	8.215	591.26	47.6	3.32

(Source : CSO)

Table 4.10 Average costs of milk production by breed of herd

	Friesian	Holstein	Jersey	Ayrshire	Average
			£ per cow		
Feed costs:					
Purchased	204.43	186.33	98.71	244.13	201.86
Home Grown	87.23	131.43	91.94	61.28	86.86
Grazing	42.68	65.94	37.01	29.24	42.90
Total	334.34	383.70	227.66	334.65	331.62
Labour cost	91.10	78.12	180.71	119.86	103.81
Misc. costs	110.08	159.82	107.85	116.04	113.75
GROSS COSTS	535.52	621.64	516.22	570.55	548.87

(Source : MMB Milk Costs Survey 1980/81)

The actual values that will be used in the evaluation for each breed are shown in Table 4.11. Although the values obtained are very rough approximates, and have involved extrapolating some very weak trends, they are the best estimates available. The first stage of the analysis that will be discussed in the following chapter examines how sensitive the initial optimal is to these cost values.

4.4.3 (ii) Costs of altering the structure of the national herd

The costs of changing the structure of the national herd could be in any of several forms. In certain circumstances the costs could amount to the cost of additional housing for cattle - if for example the desired breed happened to be of the low volume/high quality type. In other circumstances the costs of altering the national structure could be defined as the cost to the nation of a surplus of beef resulting from dairy producers discarding adult cows.

As can be imagined, the costs of changing the national herd structure are very dependent upon the type of change required. For this reason, therefore, account of the costs will be included in the discussion following the application of the model, and not in the actual initial evaluation phase.

4.4.3 (iii) The costs of an imbalance in supply and demand

In its simplest form the cost of under production is the cost of purchasing the required product from an external source. The cost of over production could be quantified as the cost of disposing of the excess product - in the case of agricultural products within the EEC this could be the cost of adding the product to intervention storage.

Table 4.11 Values used for calculating production costs for each breed using the format $y = mt + c$ where t = time

Yield	m	c
Friesian	7.29	535.60
Ayrshire	8.21	621.65
Jersey	3.43	516.23
Holstein	7.57	570.52

The values adopted for the initial stages of the analysis are rough estimates of the cost of intervention storage. They were obtained by dividing various estimates of the costs of storing dairy products by the approximate amounts in store. Having little information on these costs anyway, it will be assumed, for the purposes required in this analysis that they will stay constant over the period examined. The figures being used for the cost of overproduction are 3p/litre for liquid and 104p/kg and 33p/kg for fat and protein.

4.5 Conclusion

This chapter has focussed on examining the construction of the linear programming model that is to be applied in the following chapter. Emphasis has been on discussing possible approaches, giving justification for the methods and values used. (A complete description of the model being applied can be seen in Appendix C).

Problems have been encountered in the formulation of the model, principally in the context of the availability and comparability of data. Although it would appear that the values from the Milk Marketing Boards are more representational, it should be borne in mind that their values come only from producers involved with the recording schemes. It is believed that producers involved with the various recording schemes tend to have more efficient, higher yielding herds than those not on a scheme. (Source : Personal Communication SMMB). Factors such as this must be considered in the following analysis.

The remainder of this thesis will focus on evaluating particular instances in the UK dairy herd which could result in a need arising for some form of diversity. The analysis will involve comparing breed with gene diversity.

CHAPTER 5: Application of the linear programming model to the U.K. national dairy herd

5.1 Introduction

The purpose of this chapter is to take the model which was described in the previous chapter, and apply it to the United Kingdom dairy sector. The analysis will be carried out in two stages. Initially the current mix of breeds that together make up the national herd will be examined. For the purposes of this stage of the analysis it will be assumed that the trends and relationships between variables that existed in the periods prior to those being examined will continue. The next stage of the evaluation will be to look at the effects of certain changes, in particular how the numbers of each breed change.

The results from the analysis obtained in this chapter will be compared at a later stage with the results from achieving the required production alterations through genetic improvement of the major breed group. This comparison will then provide the basis for considering whether it is economically viable to allocate resources to maintaining and possibly developing several genetic stocks.

Analysis of the current structure of the U.K. national dairy herd will focus on a number of points which will include the trends in numbers of each breed, the sensitivity of the costs associated with production, and the significance of the penalties for over and under production in determining the optimal basis.

Before this can be accomplished, however, it is necessary to discuss how demand has been calculated for both stages of the analysis.

5.2 Demand

There are two markets for milk - the liquid market for direct human consumption, and milk for the manufacture of dairy products. Calculating demand for the latter category could be complicated slightly by the fact that traditionally the milk used for making dairy products is what is left from total supply once the demand from the liquid market has been met.

The factors that are normally regarded as influencing demand can be expressed in the form of a demand function along the following lines (Ritson, (1977)).

$$Qd = f\ (P_p, P_1, \ldots P_n, Y, N, T, I)$$

Where Qd = quantity demanded per time period;

P_p = price of the product;

$P_1 \ldots P_n$ = Prices of n other products which are regarded as competitive to p;

Y = average income per head of population;

N = number of individuals in the population;

T = tastes and preferences;

and I = distribution of income within the population.

Quantification of some of the above factors would be complex, and in some cases subjective. The formulation suggested by Ritson (1977) is general and could be applied to most products. Groves (1982) however considered the factors which influenced the demand for milk, and came to the conclusion that consumer's age and the availability of doorstep delivery greatly influenced the demand for milk.

Our method of obtaining estimates for future levels of demand for liquid, fat and protein is to calculate values based upon figures from the past decade or so, examining the allocation of milk to the various markets, and the demand for milk and milk products. This method has been employed to obtain estimates, working on the assumption that the average milk composition levels for fat and protein of 3.8% and 3.3% will continue.

An alternative approach would be to estimate the liquid markets requirements of liquid, fat and protein, and then calculate approximate requirements for the three products for manufacturing purposes.

For each of these two methods of estimating demand there are three possible views about future levels - demand could either stay more or less constant, increase or decrease. As a further complication the trends in demand for the three products do not necessarily have to move in parallel - demand for fat could fall, whilst protein demand could rise. Explanation of the above methods of calculation are demonstrated in Appendix A.

For the analysis of the current structure values obtained using the first of the above methods will be used. Values can be seen in Table 5.1. The basis for this decision is that current emphasis appears to be on liquid milk production, with secondary consideration given to fat and protein.

5.3 Analysis of the current structure

5.3.1 Introduction

The model was run for a period of five years using an objective function of minimising costs within that period. The aim of running the model in the initial stages was partly to ascertain whether the current trend in the breed

Table 5.1 Estimated demand profiles used for analysing the current structure of the United Kingdom dairy level

Demand Profile		Liquid (mn litres)	Fat (thousand tonnes)	Protein (thousand tonnes)
(i)a	Constant	15212	595	517
(i)b	Increasing	15359	601	521
		15679	613	532
		15998	626	543
		16318	638	554
		16638	651	565
(i)c	Decreasing	15069	590	511
		14929	584	507
		14792	579	502
		14658	573	498
		14526	568	493

distribution in the national level will continue, but more importantly to highlight any potentially sensitive areas which can be explored in the second stage of the analysis.

For the purposes of this evaluation, it was assumed that the UK national dairy herd initially consists of four breeds - Friesians, accounting for just over 88% of total numbers, Ayrshires (6%), Jerseys (just under 4%) and Holsteins (almost 2%). The basis for these figures are censuses carried out by the various milk marketing bodies in the early 1980's*

Initial application of the model to the national dairy herd values revealed the need for additional constraints. The model was constructed in such a way as to allow for underproduction; however, for the initial stages of the analysis no underproduction was allowed on any of the three products.

A constraint was also imposed on the number of adult heifers sold from the dairy herd, working on assumption that only a limited market exists for pure bred adult dairy heifers in the beef sector. The model is only interested in the dairy sector, and the assumption used in its construction is that the major requirement in the beef herd for female cattle originating from the dairy sector is met by transferring young calves. These transfers are represented in the model by the variable BX(B,T). A level of 2% of heifers introduced was adopted as the upper limit for adult dairy heifer sales (M(B,T)).

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*Account has not been taken at this point of figures presented by Cunningham (1983) which state that the Friesian bulls used for artificial insemination in the U.K. have 20% Holstein genes.

5.3.2. Results from the initial analysis

Results from the initial computations can be seen in Table 5.2. The figures represent the number of adult females used for production, for each breed, in each period. These values were obtained using a discount rate of 5%, which was included to take into account the concept of the time value of money. The basis of this concept is that £1 is worth more today than £1 next year. An arbitrary rate of 5% was chosen: alternative calculations were done using rates of 0% and 10%, but the structures proposed were no different to those shown in Table 5.2. The objective function used was cost minimisation.

The most striking thing about the results obtained is that demand is met primarily from the Friesian and Holstein herds. Ayrshires and Jerseys are not present in the adult herd in the initial period for a number of reasons - the main one being the economics of production with these breeds in comparison with Friesian and Holstein production costs. This will be discussed in further detail shortly. The additional withdrawals in periods 1 and 2 of Jerseys and Ayrshires is possible through the inclusion of the variable AW(B,T).

Another contributing factor to this slight anomaly in production numbers relates to the level of yield for each breed used in the calculations. The values used were based upon results obtained from milk recording carried out by the Milk Marketing Boards. A comparison of the national average annual milk yield and the average for recorded herds shows that the yields for recorded herds are approximately 500 litres/cow/year higher.

The reappearance of Ayrshires and Jerseys in period 3 is partly linked to the model formulation. In order to be able to calculate the maximum number of heifers that could be

PERIOD	BREED	DEMAND PROFILE* CONSTANT (THOUSANDS)	INCREASING	DECREASING
T=0	Friesian	2840	2840	2840
	Ayrshire	200	200	200
	Jersey	116	116	116
	Holstein	60	60	60
T=1	Friesian	2850	2828	2772
	Ayrshire	0	0	0
	Jersey	0	0	0
	Holstein	57	57	57
T=2	Friesian	2697	2781	2645
	Ayrshire	0	0	0
	Jersey	0	0	0
	Holstein	55	55	55
T=3	Friesian	2629	2766	2550
	Ayrshire	11	11	11
	Jersey	13	13	13
	Holstein	62	62	62
T=4	Friesian	2613	2807	2513
	Ayrshire	9	9	9
	Jersey	10	10	10
	Holstein	76	76	76
T=5	Friesian	2513	2759	2395
	Ayrshire	8	8	8
	Jersey	8	8	8
	Holstein	86	86	86

Table 5.2

Numbers of each breed in the national herd for different demand profiles – allowing no underproduction.

(* see table 5.1)

introduced in periods 1,2 and 3, values had to be specified for the number of females born in the three periods prior to the period of analysis.

Bearing in mind some of these factors, a series of additional computations were carried out in which changes were made to compensate for some of the above points. The resulting structures, however, all showed similar trends as to that in Table 5.2, namely, Ayrshires and Jerseys accounting for a decreasing proportion of the total herd.

As a final point it is interesting to note that changes in the level of demand for liquid fat and protein are met by altering the number of Friesians producing.

Most of the following analysis of the current structure will concentrate on the profile of constant demand.

5.3.3. Sensitivity analysis of the current structure

A simple parametric analysis was carried out on the coefficients of the objective function (the costs and benefits of production) and the values on the right hand side of the constraints. The purpose of carrying out the analysis was to determine the sensitivity of the optimal solution calculated by the model. Ranging of the right hand side values examines the range over which the shadow prices hold - the significance of which will be discussed shortly. The right hand side values of particular interest are the levels of demand for the three products in each period, and the numbers of each breed producing in the period prior to those examined (i.e. when time = -1). Ranging coefficients of the objective function gives the upper and lower values between which the variables in the objective function remain unchanged.

The results from ranging the cost of production coefficients for each breed, for the constant demand profile can be seen in Table 5.3. The figures shown are the costs of production for each breed in each time period, and by how much each could change (separately) without altering the variables in the optimal solution. If any of the changes were to occur, the variables shown would enter the optimal basis.

Prior to discussing in detail the results shown in Table 5.3, it is worth noting that the ranging analysis is only carried out on variables which appear in the optimal solution. With this in mind, it becomes apparent that Jerseys did contribute to production in periods 1 and 2. This contradicts the information reported in Table 5.2. The reason for their apparent exclusion in periods 1 and 2 is that numbers involved with production were so low that the model excluded them when it came to reporting the activity level for each variable.

The results from the parametric analysis on the costs of production show that the changes for some variables have to be extreme before the optimal basis is altered. For example, the cost of producing with Friesians in period 2 would have to increase by almost £240 per cow before Ayrshires contribute towards supply in that period. There are however a number of variables which would need only comparatively small changes to alter the optimal basis.

The deceptive thing with the results in Table 5.3 is that the ranging only takes into consideration fluctuations in a single variable at a time. In the context of the model, therefore, it could be quite difficult to achieve an increase in the cost of producing with Friesians, for example, without having some effect on the costs of using other breeds.

The values of particular interest in Table 5.3 are the costs of producing with Friesians from period 3 onwards, Ayrshires in the last period and Holsteins in period 3. The reason for

PERIOD	FRIESIAN			AYRSHIRE			JERSEY			HOLSTEIN		
	Cost	Range	Variable	Cost	Range	Variable	Cost	Range	Variable	Cost	Range	Variable
1	542.89	+19.54	F(J,2)	578.09		VARIABLES	519.66	+646.7	W(J,3)	629.86	+70.89	AW(H,1)
		-60.76	AW(H,1)			NOT IN		-16.28	F(J,2)		-509.11	SV(H,1)
2	523.98	+237.29	N(A,2)	557.77		OPTIMAL	498.18	00	-	607.69	+39.54	AW(H,2)
		-34.10	AW(H,1)			BASIS		-209.43	W(J,3)		-512.84	SV(H,2)
3	505.64	+15.22	SV(H,3)	538.08	+53.76	SV(A,4)	477.57	+11.85	SV(J,4)	586.20	+49.42	AW(H,2)
		-15.00	SV(J,4)		-91.30	BX(A,2)		-152.40	SV(J,3)		-17.62	SV(H,3)
4	487.86	+18.20	SV(H,3)	518.99	+67.19	SV(A,4)	457.79	+14.81	SV(J,4)	565.37	+56.86	AW(H,2)
		-18.76	SV(J,4)		-75.48	I(A,4)		-106.78	I(J,4)		-22.03	SV(H,3)
5	470.63	+21.71	SV(H,3)	500.51	+7.88	BX(A,3)	438.81	+18.51	SV(J,4)	545.21	+47.85	AW(H,2)
		-8.90	BX(A,3)		-66.97	SV(A,5)		-40.72	M(J,5)		-25.34	SV(H,3)

Table 5.3 Costs of production and sensitivity ranges for each of the four breeds

Explanation of symbols in Table 5.3

N(B,T) - numbers of breed B producing in time T:
B = F (Friesian);
A (Ayrshire);
J (Jersey);
H (Holstein).

I - introduction of heifers
W - Withdrawals - deaths and normal culls
AW - additional withdrawals
F - female calves born
M - heifers sold for breeding purposes to the beef herd
BX - new born female calves sold from the dairy herd

Slack variables* (SV) were needed in the model for the constraint relating to the number of adult heifers sold from the dairy herd: for example: SV(H,1) - slack variable in constraint M(H,1) = 2% I(H,1).

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* A slack variable is a variable used in linear programming which needs to be introduced into the basis to convert an inequality to an equality before an optimal solution can be obtained.

this interest is that only small changes would be required in the costs for producing in these periods for the optimal basis to change.

If the cost of producing with Friesians in the last three periods were to increase by just over 3%, the effect would be that the new optimal solution would suggest that fewer adult Holstein heifers be transferred from the dairy herd. This would result in Holsteins contributing to total supply to a greater extent from period 3 onwards.

If the costs of producing with Friesians were to drop by a similar amount in periods 3 or 4, the results from the ranging suggest that the Jersey herd would be affected. The suggestion from this result is that, as a consequence of a fall in the cost of producing with Friesians, more Jerseys would enter the herd in period 4. On first consideration, this is hard to comprehend in the context of this analysis. One interpretation could be that as a result of the fall in costs, the number of Friesians producing would increase (i.e. either more heifers are introduced, or less are culled), whereas the number of Holsteins would decrease (possibly by reducing the number of heifers introduced to the herd). Additional Jerseys would be required to make up any resulting shortage for the three products.

If the cost of producing with Friesians was to drop by just under 2% in the last period, some (if not all) of the Ayrshire calves born in period 3 would be sold from the dairy herd. This would reduce the number of Ayrshire heifers introduced to the herd in period 5. A similar effect would be obtained if the cost of producing with Ayrshires in period 5 was to increase by just over 1.5%

With regard to Holsteins, costs would only have to fall by 3% for numbers to increase. The increase would be achieved by reducing the number of adult Holstein heifers sold for breeding in the beef herd, thereby increasing the number available for dairy production.

All the results shown in Table 5.3 and discussed so far were obtained using a discount rate of 5%. Before moving away from the discussion on the sensitivity of the costs of production, it is worthwhile to examine the consequences of a different discount rate.

A run of the program was done using a discount rate of 0% to examine the sensitivity of the model to different rates in terms of both the breed structure proposed and the costs employed. Perhaps the most interesting point to arise from this additional run was the sensitivity of the costs of production for Friesians and Jerseys. From period 3 onwards comparatively small increases in the costs for Friesians would result in Jersey calves being retained in the national herd in period 1. The same effect would be achieved by decreasing the costs of producing with Jerseys from period 3 onwards.

Having examined the sensitivity of the costs of milk production, it is worth looking at some of the other coefficients in the objective function. Table 5.4 shows a number of variables, for which only comparatively small changes are necessary for the optimal basis to be altered. This table differs slightly from Table 5.3 in that the values in column 3 are the upper and lower limits for the coefficient value and not the amount by which they have to change.

Although the main reason for this part of the analysis is to examine the sensitivity of the model of the UK dairy herd, it should not be forgotten that our ultimate interest is by how much things would have to change to reduce the current dominant role of the Friesians.

Table 5.4 Analysis of the sensitivity of objective function coefficients aside from production costs

VARIABLE	COEFFICIENT VALUE £	UPPER AND LOWER LIMITS £	VARIABLE ENTERING BASIS
I(F,3)	539.68	554.90 524.68	SV(H,3) SV(J,4)
I(J,3)	317.46	329.31 165.06	SV(J,4) SV(J,1)
I(H,3)	571.43	760.69 553.81	BX(H,1) SV(H,3)
I(F,5)	489.51	513.59 480.61	SV(H,5) BX(A,3)
I(A,5)	370.22	378.10 303.25	BX(A,3) SV(A,5)
I(J,5)	287.95	00 247.23	- M(J,5)
I(H,5)	518.30	592.94 490.19	BX(H,3) SV(H,5)
AW(F,2)	-238.10	-213.68 -470.72	F(J,2) W(J,3)
M(J,4)	-95.02	-83.49 -9704.9	SV(J,4) I(J,4)
M(H,5)	-19.45	-169.34 -16132.0	SV(H,5)
BX(F,1)	-51.22	-44.31 -58.23	SV(J,4) SV(H,3)
BX(F,3)	-46.64	-42.36 -53.92	BX(A,3) SV(H,3)

(Negative objective function coefficients are income)

From Table 5.4 it can be seen that the cost of heifers entering the adult Friesian herd need only rise by just under 3% in period 3 for there to be a positive effect on the level of Holstein introductions. Costs need only fall in period 5 by under 2% for there to be a negative effect on the number of Ayrshires in the national herd.

In terms of other breeds it is interesting to note that the cost of Holstein introductions need only fall by 3% for total Holstein numbers to increase from that period. On the other hand, the cost of Ayrshire heifers would only have to rise by 2% in the final period for the optimal solution to change. The necessary change to the optimal basis would be that some (if not all) of the Ayrshire calves born in period 3 were removed from the national dairy herd in that period.

Other interesting results shown in Table 5.4 relate to the sensitivity of the income received for the sale of calves from the dairy herd (BX(B,T)). In the initial period, if the income was to fall by around £7 per head, the new optimal solution would suggest that the number of Jersey heifers entering the national herd 3 periods later should be increased. An increase in income by a similar amount, for the same period, would influence the number of Holsteins entering the herd in period 3.

Whilst on the subject of examining the sensitivity of the costs it is worth pausing briefly to examine the sensitivity of a variable that was assigned a zero value in the objective function - the number of female calves born in any period F(B,T). Table 5.5 shows the ranges of values for some of these variables.

Part of the reason for excluding the variable F(B,T) from the objective function was a slight dilemma over whether any value assigned to it should be negative or positive (that is, a benefit or a cost). If there was a cost assigned to the

Table 5.5 **Analysis of possible ranges of values for female calf births**

VARIABLE	RANGE OF VALUES	VARIABLES ENTERING BASIS
F(F,1)	7.01 -6.91	SV(H,3) SV(J,4)
F(A,1)	24.77 -42.07	SV(A,4) BX(A,2)
F(J,1)	5.46 -88.56	SV(J,4) I(J,4)
F(F,2)	6.91 -7.28	SV(J,4) SV(H,3)
F(F,3)	7.04 -4.10	SV(H,3) BX(A,3)
F(A,3)	3.63 -459.65	BX(A,2) N(A,2)
F(J,3)	44.0 -18.76	F(J,2) M(J,5)
F(H,3)	34.39 -146.8	BX(H,3) SV(H,3)

number of female calves born, it would only have to be around £7 before the optimal basis required altering. As an example in period 1, if the extra cost of Friesian female births was £7, the number of Holstein heifers entering the herd in period 3 would increase. Alternatively, if a value of £7 was placed on each Friesian female calf, the number of Jersey heifers entering the herd in period 4 would be influenced.

The final area of interest concerning the sensitivity of the costs and benefits included in the objective function is that of the values assigned to overproduction of the three products - liquid, fat and protein. The results from the ranging on these costs can be seen in Table 5.6. In the evaluation, overproduction was treated as a cost, and the values used are the approximate amount of subsidy required to dispose of surplus products.

Much of the potential benefit of this part of the analysis is unfortunately lost due to the formulation of the model. Provision has been included in the framework of the model to allow for both over and under production: however, as already stated, for this initial examination, underproduction of all products has been set at zero. The simple reason for this constraint is that at the time this project was started, the UK did not allow the importing of liquid milk for human consumption. To have allowed underproduction of fat and protein at this stage would have required giving consideration to the consequences of either shortfalls in supply or the costs of imports.

Perhaps most striking in Table 5.6 is the high upper limits for fat and protein. The analysis shows that overproduction of fat and protein would have to be treated as a benefit before changes in the variables in the optimal basis were required. In comparison, however, there is a narrow range for the cost of over producing milk. The cost would have to rise by only 2p per litre in the first period for there to be a change in the optimal basis. Although in percentage terms

Table 5.6 **Sensitivity of the costs of overproduction of milk, fat and protein**

PERIOD	PRODUCT	VALUE 1	UPPER AND LOWER LIMITS	VARIABLE ENTERING OPTIMAL BASIS
1	Milk	0.03	0.05 -0.107	F(J,2) Underproduction-protein
	Fat	1.04	4678.6 -2.02	N(A,1) Underproduction-fat
2	Fat	0.99	2229.2 -1.92	Underproduction-milk Underproduction-fat
	Protein	0.31	2580.4 -1.68	Underproduction-milk Underproduction-protein
3	Milk	0.03	0.285 0.010	SV(J,3) SV(J,4)
	Fat	0.94	451.09 -1.83	SV(J,4) Underproduction-fat
4	Milk	0.03	0.114 0.006	SV(H,3) SV(J,4)
	Fat	0.90	408.64 -1.74	SV(J,4) Underproduction-fat
5	Fat	0.86	344.22 -1.66	SV(J,4) Underproduction-fat
	Protein	0.27	763.02 -1.45	SV(J,4) Underproduction-protein

1 The units of measures are £/litre for milk, and £/kg for fat and protein

this is a large increase, it is not totally improbable, especially considering the concern currently being given to the high level of overproduction of milk within the EEC.

Taking an overall view of the results in Tables 5.3 to 5.6, it could be said that for the most part the current structure is fairly insensitive to minor changes in costs. The exceptions to this statement are possible values for female calves and the cost of over production of milk. Another possible area would have been the value of Holsteins outwith the dairy sector - at present there is still some resistance from butchers towards the Holstein carcase (Personal Comm. MLC). The analysis of the current structure suggests, however, that the income from the sale of Holstein calves leaving the dairy sector would have to double before a change occurs in the optimal basis.

To date the analysis has focussed solely on the sensitivity of the costs involved with the current structure. It is also worth looking at the sensitivity of some of the right hand side values in the model, in particular the demand for the three products. The main difference in the output from this analysis is that the variables that will <u>leave</u> the optimal basis are mentioned. Table 5.7 gives the results from conducting a parametric analysis on the demand values for the three products.

Examinations of the results in Table 5.7 reveals little of interest regarding the sensitivity of the optimal structure, the exception being the consequences of increasing the demand for protein in periods 3 and 4. In isolation the discovery that an increase in the demand for protein in these periods will influence the number of Friesian calves kept in the dairy herd is not particularly startling; however, if one also considers some of the shadow prices* an interesting point

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*Shadow prices: the costs that would be incurred through using an additional unit from the level calculated in the optimal basis.

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*Shadow prices: the costs that would be incurred through using an additional unit from the level calculated in the optimal basis.

Table 5.7 Sensitivity of the demand constraints

PERIOD	PRODUCT	DEMAND*	% CHANGE	VARIABLE LEAVING BASIS
1	Milk	15212	+2.25 00	Milk overproduction period 1
	Fat	595	+1.32 00	Fat overproduction period 1
	Protein	517	+0.88 -1.30	AW(F,1) Fat overproduction
2	Milk	15212	+3.86 -1.32	AW(F,2) Protein overproduction period 2
	Fat	595	+2.02 00	Fat overproduction period 2
	Protein	517	+1.34 00	Protein overproduction period 2
3	Milk	15212	+0.19 00	Milk overproduction period 3
	Fat	595	+0.62 00	Fat overproduction period 3
	Protein	517	+6.48 -0.20	F(F,2) Milk overproduction period 2
4	Milk	15212	+1.73 00	Milk overproduction period 4
	Fat	595	+0.58 00	Fat overproduction period 4
	Protein	517	+2.16 -0.57	F(F,3) Fat overproduction period 4
5	Milk	15212	+19.00 -1.47	BX(F,3) Fat overproduction period 5
	Fat	595	+1.49 00	Fat overproduction period 5
	Protein	517	+1.59	Protein overproduction period 5

(* milk = mn litres , fat and protein thousand tonnes) emerges.

In periods 1,3, and 4 there is no over production of protein. If additional protein was required in period 1, there would be no additional withdrawals of Friesians in that period. The cost of every additional tonne of protein would be in the region of £4000. Values of a similar magnitude would occur as a result of additional quantities of protein in periods 3 and 4. In contrast, however, is the shadow price for milk. The model suggests no overproduction of liquid in period 2 - the additional cost for an extra unit of milk is insignificant. The other area of right hand side values that is interesting to explore is the changes necessary for there to be an increase in the number of Jerseys or Ayrshires in the first two periods. Results from the parametric analysis suggest that for Ayrshires and Jerseys to play an increased role in the initial periods the number of Friesians producing in the periods prior to the model would have to drop by a least 36 thousand head. The suggestion from numbers for periods 3 to 5 is that if Friesian numbers were to fall, the number of Jerseys would increase.

From all the analysis carried out on the current structure, the most probable change which would result in an increase in the number of Ayshires would be for the income received for the additional culls of the breed in period 1 to fall by 20%. With this in mind, a revised version of the model of the current structure was run, setting minimum levels for the number of Ayrshires and Jerseys producing in the initial periods. The basis of the minimum levels used was the registrations of pedigree heifers with the respective breed societies, and the assumption that introductions account for around 20% of the total herd in a particular period. Provision was also included for the drop in numbers of these two breeds in the national herd over recent years. The results from this analysis are shown in Table 5.8.

PERIOD	BREED	NUMBERS PRODUCING ('000)
T=0	Friesian	2840.0
	Ayrshire	200.00
	Jersey	116.0
	Holstein	60.0
T=1	Friesian	2714.58
	Ayrshire	67.00
	Jersey	33.00
	Holstein	57.31
T=2	Friesian	2620.89
	Ayrshire	62.00
	Jersey	30.00
	Holstein	55.16
T=3	Friesian	2565.50
	Ayrshire	60.77
	Jersey	37.04
	Holstein	62.12
T=4	Friesian	2559.78
	Ayrshire	48.62
	Jersey	29.63
	Holstein	75.84
T=5	Friesian	2462.96
	Ayrshire	52.82
	Jersey	23.70
	Holstein	86.34

Table 5.8

Numbers of each breed producing in the national herd,with a constant demand, 5% discount rate and minimum levels for the numbers of Ayrshires and Jerseys in Periods 1 and 2

A comparison of the results from this analysis with the values in Table 5.2 shows that the constraint on Ayrshire and Jersey numbers is met by a reduction in Friesian numbers. The number of Holsteins producing in the national herd does not change. It is also interesting to note the fluctuations in the numbers of Ayrshires and Jerseys from period 3 onwards - this is presumably due to the economic relationships between some of the variables. It could, for example, be financially more beneficial to use Ayrshires and Jerseys for production in later periods, whilst receiving income from the sale of Friesian calves several periods earlier.

An area of the output from the analysis of the current structure that has not been discussed is the objective function. The results from this initial analysis could be questioned in that the model only considers a comparatively short period of time, and that within the period its objective is cost minimisation. The choice of objective and the model formulation has led to the optimal solution suggesting certain anomalies, such as that no female calves should be kept in the national herd in the last two periods.

The reason for this anomaly is simply that the full consequences of selling all female calves would not be felt during the period of evaluation, and that a benefit, which would contribute to the objective of cost minimisation, could be derived from these calves in the short term by selling them from the national herd. This problem could be overcome by either running the model for say 8 periods, making use of the results from the initial five periods. Alternatively a value could be assigned to the pure bred female calves in order to ensure a stock was available for introducing to the herd after period 5.

As a result of these slight peculiarities, the actual value of the objective function in its present form has little significance when used in isolation. It will have a value, however, when comparing different structures.

5.3.4 Summary to the analysis of the current structure

The purpose of this initial analysis of the UK dairy herd model has been to identify possible areas which, if changed, could result in alterations being made to the structure of the national herd. For the most part, the current structure appears fairly insensitive to changes in costs of the type and level that would affect one breed only. The exception to this (for the values and formulation used) would appear to be the cost of overproducing liquid. Bearing this in mind, along with some of the outcomes from the examination of the sensitivity on the levels of demand used, further analysis will be carried out in this area.

The remainder of this chapter will focus on possible alternative future demand profiles in order to try to identify levels and patterns of demand which would require the national herd to comprise of more than just the black and white breeds. Results from this analysis will then be compared in following chapters with achieving any required alterations to the herd through genetic means.

5.4 Possible future demand structures

5.4.1 Introduction

The evaluation has so far centred around the demand for three products - the requirement for each of which could either fall, increase or stay constant independent of the demand for the other two products. In addition there is a range of other possible future profiles which could occur either through changes in emphasis within the dairy retail sector, or as a result of changes in EEC legislation.

As a result of the wide choice of possible future demand profiles, a series of single period analyses were conducted to determine theoretical optimal breed structures for the national herd. The objective of cost minimisation was applied, but only included costs of producing, plus the costs of overproduction. No account was taken of the costs that would be incurred arriving at these optimal structures.

The model applied was simply a set of equations ensuring that supply met demand for all products, with no constraints being imposed on the numbers of each breed. Any interesting results from this analysis were then examined in the multi-period context. Results of initial interest were those which suggested an optimal basis which included more than just Friesians.

5.4.2 Single period analysis of possible future demand profiles

Results from the single period can be seen in Table 5.9. These results were obtained using the costs and yields as at period 1 in the main model. The changes calculated for the demand profiles was plus or minus 10% of the base case (profile number 14). Two further profiles were also examined: profile number 28 assumes UK self-sufficiency in fat, whereas profile 29 is based on the assumption that the emphasis is switched to liquid plus requirements of all products for manufacturing purposes (see Appendix A).

There are two main striking features about the structures shown in Table 5.9 - firstly the apparent lack of need for Ayrshires in the range of profiles tested, and secondly the strong position held by the Friesian. The reason for Ayrshires being excluded would appear to be their high cost of production per unit of output - particularly in comparison with the Friesian. Even allowing for a reduction of £50 in costs per cow, Ayrshires would not enter the optimal basis, unless either the cost of liquid overproduction rose by 7½p per litre, or the penalty for overproduction of fat was £18 per kilogram.

Table 5.9 **Single period analysis results on possible future demand profiles**

Profile No.	Demand			Numbers Producing (000's)			
	Liquid (mn Litres)	Fat (thousand tonnes)	Protein	Friesian	Jersey	Holstein	Ayrshire
1	16733	654.5	568.7	3125			
2	16733	654.5	517.0	3053	52		
3	16733	645.5	465.3	3053	52		
4	16733	595.0	568.7	3125			
5	16733	595.0	517.0			2670.5	
6	16733	595.0	465.3			2670.5	
7	16733	535.5	568.7	3125			
8	16733	535.5	517.0			2670.5	
9	16733	535.5	465.3			2670.5	
10	15212	654.5	568.7	3125			
11	15212	654.5	517.0	1986	1195		
12	15212	654.5	465.3	1979	1205		
13	15212	595.0	568.7	3125			
14	15212	595.0	517.0	2841			
15	15212	595.0	465.3	2775	48		
16	15212	535.5	568.7	3125			
17	15212	535.5	517.0	2841			
18	15212	535.5	465.3			2428	
19	13691	654.5	568.7	3125			
20	13691	654.5	517.0	1085	2164		
21	13691	654.5	465.3	909	2352.5		
22	13691	595.0	568.7	3125			
23	13691	595.0	517.0	2841			
24	13691	595.0	465.3	1709	1190		
25	13691	535.3	568.7	3125			
26	13691	535.3	517.0	2841			
27	13691	535.3	465.3	2557			
28	15212	721.0	517.0	1104.5	2477		
29	10448	595.0	349.4		3020		

With regard to the strong position held by the Friesian, in many of the profiles shown in Table 5.9 it would appear to be cheaper to overproduce than to move to other breeds. The penalty for overproducing liquid would have to rise to just over 17p per litre (an increase of almost 600%) before it became necessary to change the herd structure to retain optimality. In the event of such an increase the analysis recommends that the Jersey enters the national herd producing alongside the Friesian.

In the light of some of the results obtained in the single period analysis, Figure 5.1 was drawn up to help identify which breeds would be optimal for different levels of demand. The demand for fat and protein in this instance have both been expressed as a percentage of liquid demand. The boundary lines were obtained from the results of a parametric analysis on the levels of demand used.

The main area of interest arising from both Table 5.9 and Figure 5.1, in the context of this research, is the range of possible demand profiles for which the optimal herd structure would include breeds either in place of, or in addition to Friesians. A number of these exist and have been taken a stage further. This next stage of the analysis involves comparing the results from the profiles of interest over a number of years, with the costs of having a UK herd made up of solely Friesians.

5.4.3 Multi-period analysis

A three-way comparison was carried out on a number of possible future demand profiles. The profiles subjected to this further analysis were numbers 8,12,15,18,20,21 and 29 from Table 5.9. Results can be seen in Table 5.10.

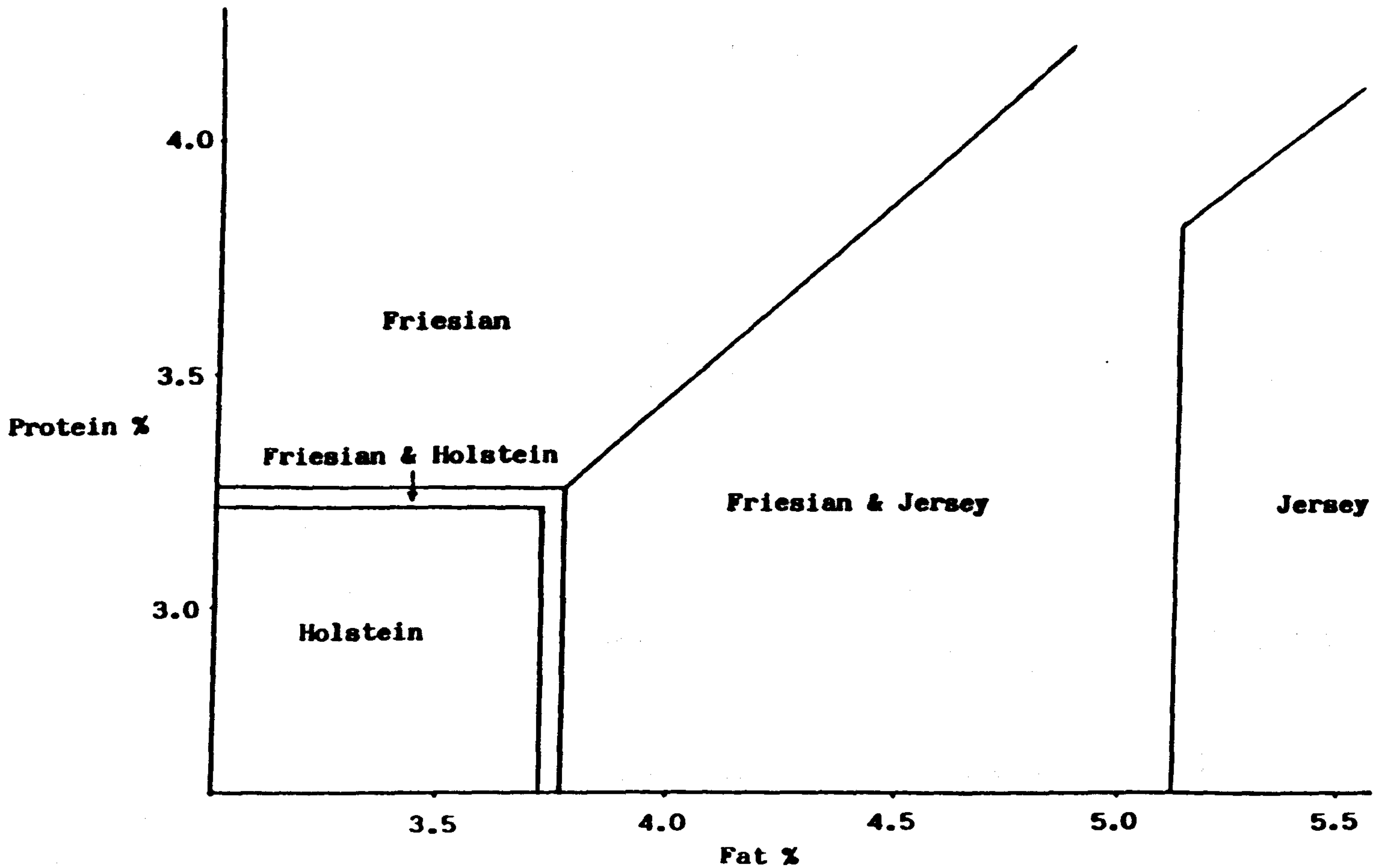

Figure 5.1 Optimal breed mixes for various levels of demand for protein and fat

Table 5.10 Triple comparison of possible future demand profiles

(i) Profile number 8 - Milk 16733mn litres
Fat 535.5 thousand tonnes
Protein 517 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk	Fat	Protein	Costs
		(Thousands)			(mn litres)	(thousand tonnes)		(£bn)
1	2831	182	43	57		116	42	1.83
2	2823	168	-	55		133	60	1.76
3	2776	145	13	62		122	51	1.65
4	2738	116	10	76		112	43	1.56
5	2668	130	8	86		129	61	1.50
								8.30
1	3089					116	45	1.81
2	3037					117	48	1.72
3	2986					118	50	1.64
4	2937					119	53	1.55
5	2889					120	55	1.48
								8.20
1				2670		108	38	1.81
2				2619		109	43	1.71
3				2569		109	48	1.62
4				2522		110	50	1.54
5				2475		110	55	1.46
								8.14

Table 5.10 (Continued)

(ii) Profile number 12 - Milk 15212mn litres
Fat 654.5 thousand tonnes
Protein 465.3 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk (mn litres)	Fat (thousand tonnes)	Protein (thousand tonnes)	Costs (£bn)
		(Thousands)						
1	2831	102	119	57	1419		98	1.77
2	2823	43	122	55	1372		98	1.67
3	2739	46	138	62	1299		97	1.58
4	2648	36	166	76	1213		96	1.49
5	2556	39	190	87	1124		95	1.40
								7.91
1	3102				1586		99	1.76
2	3044				1561		101	1.67
3	2988				1536		102	1.59
4	2935				1508		104	1.51
5	2883				1485		105	1.41
								7.94
1	1979		1205				74	1.72
2	1967		1158				73	1.63
3	1961		1103				75	1.54
4	1977		1018				73	1.45
5	1956		988				74	1.37
								7.71

Table 5.10 (Continued)

(iii) Profile number 15 - Milk 15212mn litres
Fat 595 thousand tonnes
Protein 465.3 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk	Overproduction Fat	Overproduction Protein	Costs
	(Thousands)				(mn litres)	(thousand tonnes)		(£bn)
1	2675		97	57			43	1.55
2	2697			55		12	59	1.48
3	2623	11	13	62		2	51	1.39
4	2597	9	10	76	173		49	1.34
5	2513	8	8	86		9	60	1.26
								7.02
1	2820				63		48	1.55
2	2767				37		49	1.47
3	2717				13		51	1.39
4	2670					0.5	53	1.32
5	2627					1	55	1.25
								6.98
1	2775		48				47	1.55
2	2742		27				49	1.46
3	2708		10				51	1.39
4	1949			618			50	1.31
5	1739			761			53	1.25
								6.96

Table 5.10 (Continued)

(iv) Profile number 18 - Milk 15212mn litres
Fat 535.5 thousand tonnes
Protein 465.3 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk (mn litres)	Fat (thousand tonnes)	Protein (thousand tonnes)	Costs (£bn)
		(Thousands)						
1	2742			57		54	40	1.59
2	2697			55		72	59	1.54
3	2623	11	13	62		62	51	1.45
4	2566	9	10	76		53	43	1.36
5	2513	8	8	86		68	60	1.31
								7.25
1	2809					57	46	1.60
2	2761					58	48	1.52
3	2714					59	50	1.44
4	2670					60	53	1.37
5	2627					61	55	1.30
								7.23
1				2428		50	40	1.59
2				2381		50	44	1.51
3				2335		51	48	1.43
4				2292		51	50	1.36
5				2250		52	54	1.28
								7.17

Table 5.10 (Continued)

(v) Profile number 20 - Milk 13691mn litres
Fat 654.5 thousand tonnes
Protein 517 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk	Overproduction Fat	Overproduction Protein	Costs
	(Thousands)				(mn litres)	(thousand tonnes)		(£bn)
1	2831	118	119	57	3016		42	1.81
2	2823		122	36	2557		45	1.65
3	2787	11	137	47	2813		45	1.61
4	2736	9	164	63	2997		43	1.55
5	2587	8	188	71	2548		48	1.41
								8.03
1	3102				3112		47	1.79
2	3044				3083		49	1.70
3	2988				3057		51	1.61
4	2935				3030		52	1.54
5	2883				3006		54	1.43
								8.07
1	1085		2164		250			1.72
2	1056		2138		200			1.62
3	1094		2034		225			1.53
4	1194		1861		331			1.44
5	1164		1844		298			1.36
								7.67

Table 5.10 (Continued)

(vi) Profile number 21 - Milk 13691mn litres
Fat 654.5 thousand tonnes
Protein 465.3 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk (mn litres)	Fat	Protein (thousand tonnes)	Costs (£bn)
		(Thousands)						
1	2831	118	119	57	3016		94	1.82
2	2823		122	36	2557		97	1.67
3	2787	11	137	47	2813		97	1.62
4	2236	9	164	63	2997		95	1.57
5	2587	8	188	71	2548		100	1.42
								8.10
1	3102				3112		99	1.81
2	3044				3083		101	1.72
3	2988				3057		102	1.63
4	2935				3030		104	1.55
5	2883				3006		106	1.44
								8.15
1	909		2352				47	1.73
2	918		2286				48	1.63
3	943		2196				47	1.54
4	976		2095				46	1.45
5	971		2052				46	1.37
								7.72

Table 5.10 (Continued)

(vii) Profile number 29 - Milk 10448mn litres
Fat 595 thousand tonnes
Protein 349.4 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk	Fat Protein	Costs
		(Thousands)			(mn litres)	(thousand tonnes)	(£bn)
1	2720		119		4729	158	1.73
2	2594		121		4307	162	1.60
3	2553	11	137	15	4537	161	1.56
4	2514	9	164	22	4704	159	1.50
5	2388	8	187	18	4284	164	1.35
							7.74
1	2820				4827	164	1.73
2	2767				4801	165	1.64
3	2717				4777	167	1.57
4	2668				4752	168	1.49
5	2621				4731	169	1.37
							7.80
1			3020		806	94	1.62
2			2975		788	97	1.53
3			2917		717	94	1.44
4			2860		648	91	1.35
5			2820		634	90	1.27
							7.21

The comparison was made by applying the multi-period analysis, described earlier, to the possible demand profiles, to determine how producers would react in the short term if the changes were to occur. Results from this analysis (the numbers of each breed and costs) were then compared with the costs that would be incurred if the UK dairy herd was 100% Friesian. These values were also compared with the theoretical optimal calculation using the single period model.

The values for 100% Friesian were calculated on the basis of the minimum number necessary to fulfill demand for all three products. The reason for calculating these numbers was that recent trends suggest that, unless the status quo is altered, within a decade or so the UK dairy herd will be practically 100% Friesian and Holstein.

In many ways it would have been more accurate if the costs were calculated for a combined Friesian/Holstein herd, particularly when one considers that in 1979 Holstein genes accounted for 13.6% of the Friesian population used for artificial insemination. By 1981 Holstein genes accounted for 26.3% (Cunningham 1983). These values are further supported when one looks at the results from applying the single period model to the current demand profile (profile number 14), but for period 5. The optimal structure in this instance would be a herd made up of 69.6% Friesian and 30.4% Holstein. For the sake of convenience, however, a structure of 100% Friesian will be used.

The reason for this comparison is to try and show what would be theoretically optimal under the conditions as at time t=0, in comparison with what would be ideal if there was both breed diversity and a higher degree of flexibility than at present. The results from these situations can then be compared with the situation that would arise as a result of little or no diversity in the national herd. As with previous calculations a discount rate of 5% was used.

From this triple analysis it can be seen that for the demand profiles which have a proportionally higher fat demand, it is theoretically better to have an element of diversity available in the national herd. Diversity in this context refers to breeds other than the Friesian and Holstein. The basis for this statement is a comparison of the values in Table 5.10, a summary of which can be seen in Table 5.11.

The values in Table 5.11 show the theoretical saving in the costs of production from having a national herd which includes a percentage of the high fat producing stock, in comparison with an all Friesian herd. It should be borne in mind that the figures relate to discounted gross costs and do not take into account factors such as the costs of having the diversity available in the first place, the effect of such optimal structures on other livestock sectors, or the rate of acceptance or change from the current herd structure to the desired optimal. These factors will be considered, in conjunction with the above results, when a comparison is made between breed and gene diversity.

With regard to the results shown in Tables 5.10 and 5.11, it is interesting to note two factors. Firstly, if the costs used for overproduction (milk 3p per litre, fat £1.04 and protein 33p per kg) were excluded, the optimal structure for all four of the profiles in the latter table would be 100% Friesian.

The second point relates to the level of output from each breed, and is best demonstrated by making reference to the most extreme of the demand profiles (profile number 29 in Table 5.9), which amounts to a 31% drop in liquid and a 32% fall in protein demand. Assuming all other things would stay constant, the fat yield for Friesians would only have to increase by 5.3% to 222 kg per cow in period 1 for the optimal solution to be once again 100% Friesian.

Table 5.11 Summary of results in Table 5.10 showing possible savings in a national herd

Demand Profile Milk (mn litres)	Fat (thousand tonnes)	Protein	Percent Jersey Period 1	Period 5	Saving Over 5 years (£m)
15212	654.5	465.3	37.8	33.5	230
13691	654.5	517.0	66.6	61.3	400
13691	654.5	465.3	72.1	67.8	430
10488	595	349.4	100.0	100.0	590

All the demand structures tested so far - with the exception of profile number 29 - have been concerned with comparatively conservative changes ($\pm$ 10% of the base case). Prior to concluding this analysis using the L.P model it is worth testing certain extremes.

In the base case the demand for domestically produced fat was 3.8% of liquid and protein 3.3%. Extremes for both cases could be demand at 1% of liquid requirements. This would be equivalent to a 73.7% drop in the demand for fat and a 69.7% drop for protein. Results from a triple analysis on these extreme levels can be seen in Table 5.12.

From the results for both of these extreme profiles, it could be deduced that there is not much call for breeds other than the Friesian and Holstein, except for low numbers of Jerseys for the first three periods of the first of the two profiles. What it therefore becomes interesting to determine is whether or not the level of overproduction in both cases could be reduced - genetically - at what would amount to a lower cost than the penalty imposed for over production. The costs incurred in these particular instances for overproduction are approximately £540m for the low protein profile, and £2bn for the low fat profile over the 5 year period. This area will be discussed further in the comparison of breed and gene diversity.

5.4.4 Limitations and problems arising from the multi period analysis

The main limitation of the model that has been applied to produce the results in Tables 5.10 and 5.12 is that no provision was allowed for crossbreeding within the national herd. Any move away from one breed to another suggested in the model results is achieved by the natural process of culling the less desired breed, whilst breeding pure as many of the required breed. To allow for crossbreeding in the model, each cross or combination of breeds would have to be

Table 5.12 Results from testing extreme values for (i) protein
(ii) fat

(i) Profile - Milk 15212mn litres
Fat 595 thousand tonnes
Protein 156.6 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk (mn litres)	Fat	Protein (thousand tonnes)	Costs (£bn)
		(Thousands)						
1	2707		50	57			357	1.65
2	2700			55	21		358	1.56
3	2623	11	13	62		1.6	359	1.54
4	2566	9	10	76		3.0	360	1.41
5	2512	8	8	87		4.7	361	1.34
								7.50
1	2812				70		358	1.65
2	2767				37		358	1.56
3	2717				13		359	1.48
4	2670					2.8	360	1.40
5	2627					4.5	361	1.34
								7.43
1	2772		53				357	1.65
2	2752		12				357	1.56
3	2708		10				359	1.48
4	1949			618			359	1.40
5	1739			761			362	1.33
								7.42

Table 5.12 (Continued)

(ii) Profile - Milk 15212mn litres
Fat 156.5 thousand tonnes
Protein 517 thousand tonnes

Period	Friesian	Ayrshire	Jersey	Holstein	Overproduction Milk	Fat	Protein	Costs
		(Thousands)			(mn litres)	(thousand tonnes)		(£bn)
1	2767			57	137	441		2.00
2	2713			55	91	441		1.89
3	2631	11	13	62	44	442		1.79
4	2568	9	10	76	10	442		1.70
5	2512	8	8	87		443	1	1.61
								8.99
1	2833				133	441		2.00
2	2778				96	441		1.89
3	2721				37	439		1.79
4	2673				19	442		1.70
5	2627					443	0.7	1.61
								8.99
1	2833				133	441		2.00
2	2778				96	441		1.89
3				2350	94	433		1.78
4				2298	36	432		1.69
5				2250		431	2.8	1.59
								8.95

treated as a new breed, which even over the short period of evaluation could result in the number of significant variables increasing quite considerably for little additional benefit.

Provision, however, can be made for crossbreeding in the multiple single period analysis that was carried out. The traits of interest in this evaluation - milk, fat and protein yield - are not subject to the phenomenon known as hybrid vigour. This allows us to assume that the yield from a crossbreed offspring can be approximated as half the sum of the parents yield. Taking this, along with the fact that costs have been assumed to be linear, allows the results from the single period analysis to be interpreted in two ways.

In profile number 12, the theoretical optimal recommendation is that in period 5, the national breed should be made up of just under 2 million Friesian and just under 1 million Jersey cows. This could also be taken to mean that the optimal herd would be one in which Jersey genes accounted for 33⅓% of the genetic population - the balance being Friesian genes.

Three further areas of the model that warrant discussion are the period over which the analysis was conducted, certain peculiarities of the solutions suggested in particular cases and the data used.

The period over which the analysis was conducted was determined by a number of factors - the main one being the method of forecasting. Ideally, the model should have been run for a period of at least 15-20 years, with the detailed analysis focussing on the sensitivity of the variables during the first ten years or so. Using an extended period of 15-20 years would have resulted in problems over the forecasting of yields and costs for each breed. The basis for forecasting these values in the analysis was by linear extrapolation of recent trends. To have assumed that the recent rates of change would continue for 20 years would have been unrealistic, particularly when one considers how average yields have increased in recent years. To obtain usable forecasts for use over a longer period would have required an in-depth econometric analysis.

A further constraint on the period examined was the capacity of the computing facilities. Carrying out the analysis over five periods resulted in a model size of 170 variables and 115 constraints. Increasing the period covered by a further year would have added a further 34 variables and 23 constraints to the model size. Any significant increase in the period covered by the model, would have exceeded the capacity of the computing software that was available.

The computing software that was used to run the model resulted in restricting the value of the output. The analysis that was carried out on the optimal solution proposed by the model involved examining the consequences of changing the activity level of one variable at a time.

Having a full parametric analysis capability would have enabled the examination to consider the consequences of a series of possible changes together.

The second problem area relates to some of the solutions suggested by the model. For some of the profiles examined, the model suggested that certain breeds should leave the optimal basis, returning in later periods. This was caused by a combination of factors relating to the model formulation. The model only considered a period of 5 years, during which the objective was to minimise overall costs. As a result, revenue was raised in later periods of the analysis by selling Friesian and Holstein cows for beef, having little regard for production requirements from period 6 onwards. In such circumstances it was cheaper to introduce heifers from other breeds.

A possible way around this peculiarity would have been to impose constraints in later periods limiting the sale of animals for beef. The desire, however, was to leave the model unconstrained wherever possible, allowing trends in breed numbers to be identified more clearly, which perhaps would only have become apparent over a longer period in a constrained model.

An alternative solution to this peculiarity would have been to introduce some form of conditional constraint into the model. The use of conditional statements would have allowed constraints such that if the numbers of a particular breed were less than one in any period, numbers for that breed in subsequent periods were set to zero. Unfortunately, linear programming does not readily allow for conditional statements. A solution to this problem would have been possible if integer programming techniques had been employed.

The third area for discussion relates to the data used in the analysis. Most of the figures used came from various Milk Marketing Board publications with the breed specific information coming from MMB surveys of producers involved with milk recording schemes. As already mentioned, yields of animals involved with milk recording schemes tend to be higher than the national average. The information used, however, was the best and most complete that was available at the time. Other costs and yields could have been obtained from individual breed societies or feed manufacturers. The sample sizes, however, for these sources were not as extensive as the MMB, and the figures could not be regarded as representational.

The second problem relating to the data is that although the analysis is carried out in terms of the UK as a whole, much of the information obtained came from the MMB for England and Wales. Only limited information was available from the Scottish MMB and the MMB for Northern Ireland.

The breed that probably fared worse from the data problems was the Holstein. At the time to which the figures relate (the late 1970's and early 1980's), the Holstein was very much a new breed in the UK. In 1978/79, Holsteins accounted for only 1.4% of the total herd in England and Wales. There was opposition towards the breed from butchers and meat processors which resulted in an artificially low price for Holsteins sold for beef. This initial resistance now seems to have been overcome, and numbers have increased substantially.

5.5 Conclusion

The basis for this chapter has been the application of the linear programming model of the United Kingdom dairy herd which was discussed in Chapter 4. The analysis was carried out in the two stages. Initially, attention was focussed on the current structure of the national herd, with the purpose of identifying possible areas of cost which could in future call for changes to be made. Changes of interest were those that would cause or result in a move away from the current dominant breed - the Friesian.

The results from this analysis of the current structure indicate that in general the existing mixture of breeds and trend in numbers is insensitive to fluctuations in cost of the type that would affect one breed only. The exception to this conclusion however, is the penalty for overproduction of liquid, and the income from the sale of calves from the dairy sector.

Effects from changes in the income from sales are minimal according to the model, resulting in only small changes in the optimal basis. Analysis of the current structure, along with possible future demand profiles, shows that increases in the penalty for overproduction would tend to favour the Jersey breed. The extent to which the penalty has to increase for this to happen depends upon the level of demand for the three products.

The second stage of the analysis involving the model turned its attention to possible future demand profiles to try to identify whether a need for diversity exists. In the context of this stage of the evaluation, diversity is taken to mean breeds other than the Friesian and Holstein. The analysis, which involved several phases, identified that for demand profiles with a proportionally high demand for fat it could be economically advantageous to have diversity available.

The last section of the analysis of possible future demand profiles focussed on two extremes - milk and fat demand constant, with protein demand very low, and milk and protein constant with fat demand low. Neither of these structures, when subjected to the analysis using the existing cost relationships, demonstrated a need for breed diversity. These demand profiles did however provide an interesting avenue to explore with regard to gene diversity - namely whether through having diversity the level of overproduction arising from such profiles could be reduced, making overall savings in costs.

This chapter has provided the basis for the remainder of this thesis in that possible economic benefits from having diversity have been identified. The analysis has also raised the question of whether there are economic benefits to be had by having the ability to reduce overproduction of one or more of the products by genetic means.

The dilemma of whether it is advantageous to have breed or gene diversity will be discussed in detail in the next chapter. The evaluation will consider some of the costs associated with diversity which were not included in the model.

Chapter 6 A comparison of genetic improvement with breed substitution

6.1 Introduction

In the preceding chapter a number of possible different demand profiles were identified for which the theoretical optimal mix of breeds for the U.K. national herd would include breeds other than Friesian and Holstein. The criterion used for determining optimality in all cases was cost minimisation subject to constraints on the level of output for each of the three characteristics - milk, fat and protein. Results from this analysis indicated that the profiles requiring breeds other than Friesian and Holstein were where demand for fat was high in comparison to liquid and protein requirements. The likelihood of such profiles occurring will be discussed at a later stage.

The purpose of this chapter is to take the results obtained in Chapter 5 and compare them with the results from fulfilling the required demand profiles with a 100% Friesian herd - the output and composition from the individual cow having been altered by human intervention.

Attention will initially focus on some of the basic principles involved with altering the levels of production for the three characteristics. Levels can be adjusted by genetic and dietary means. The discussion will then attempt to quantify some of the costs and benefits of genetic improvement, as well as mentioning some of the additional costs incurred through using breed substitution that were excluded from the linear programming analysis. At this point the subject of time lags and the problem of getting producers to change their production styles will be broached. The chapter will conclude with a summary of the relative merits of breed substitution and genetic improvement before going on to discuss some of the broader issues in the final chapter.

6.2 Altering production levels

6.2.1 Adjusting yields through changes in diet

A comprehensive analysis of the methods of altering the output of dairy cows through adjusting their diet is not essential for the purposes of this evaluation. Reference will be made to Rook and Thomas (1980), Sutton (1984) and Wilson and Lawrence (1984), who together review the "state of the art".

Of the two milk products of interest in this analysis, more is known about altering fat yield and fat concentration. Sufficient reliable information is not yet available to enable protein to be manipulated accurately by dietary means with any confidence (Rook and Thomas (1980)). Fat percentage, however, can be increased by using either protected lipid supplements or by increasing the fibrous content of the diet.

Diets lacking or low in fibre increase the uptake of proprionic acid from the rumen and depress the secretion of milk fat (Rook and Thomas (1980)). This is supported by the figures in Table 6.1 which show the effect of changing the proportion of cereal in the diet on milk yield and composition. The use of protected lipid supplements in the diet could increase fat yield from normal diets by 25-30% (Storry, Brumby and Dunkley (1980)).

With regard to protein output, metabolic experiments were carried out the results of which suggested that increasing

TABLE 6.1 **Effect of the proportion of concentrates in the diet on milk yield and composition and yield of fat and protein**

Concentrate level	Milk yield	Composition level		Yield	
		Fat	Protein	Fat	Protein
	Kg/day	%	%	Kg/day	Kg/day
60% Barley	16.1	4.49	3.15	0.73	0.51
90% Barley	20.6	2.06	3.03	0.42	0.62
60% Maize	18.9	4.04	3.00	0.76	0.56
90% Maize	15.6	2.97	3.43	0.46	0.54

(Source: Sutton, Oldham and Hartt (1980)) proprionic acid supplies in the rumen would increase milk protein concentration (Rook and Balch (1961)). Subsequent feeding trials, however, failed to establish a relationship supporting these results. Other research found that milk protein concentration can be increased by 0.1-0.2% by increasing the proportion of concentrates in mixed hay and concentrate diets (Gordon and Forbes (1971)). There is, however, little response if the diet already comprises 50-60% concentrates.

The area that appears to be receiving a lot of attention with regard to altering protein output, is the use of protected protein in the diet. The input protein is soyabean, or something similar, protected by formaldehyde. Diets of this kind have been found to increase milk yield and protein content in cows and heifers during early lactation (Kaufmann and Lupping (1980)). Problems were encountered however with the digestibility of the diet.

As can be seen from this brief review, work is being done in the area of altering yields through dietary changes. Much of this work, however, still appears to be only at the experimental stage.

No information appears to be available concerning the application of some of the above dietary changes to commercial herds, giving indications of whether dairy producers can match the level of change achieved at the experimental stage. The potential implications towards costs of production also appears to be unavailable. For these reasons the option of adjusting output by dietary means will not be included to any great extent in the quantitative aspects of this analysis.

This exclusion is a pity, particularly considering the scale of changes possible indicated by the figures in Table 6.1. Ideally, further work should be conducted by nutritionalists, focusing attention on the applicability of some of the methods mentioned to commercial herds, and whether the improvements can be sustained easily.

6.2.2 Changing yields by means of genetic improvement

The improvement of yields by genetic improvement and selection has already been applied to commercial livestock populations. It is not proposed that this section will explore the recognised formulae for calculating improvement, but to focus on some of the theoretical potential changes. Where necessary, references will be made to Falconer (1981), Dalton (1980) and Smith (1984c).

Values showing the theoretical genetic improvement for selecting directly on particular traits in dairy cattle can be seen in Table 6.2. The method used for calculating these results is briefly explained and demonstrated in Appendix B.

Selection and improvement on any of the traits used in this evaluation will result in changes in the other traits (because of genetic correlations between traits) unless a conscious effort is made. In such cases where restrictions are imposed to prevent correlated responses, the annual improvement possible in the main trait is less. Table 6.3 gives some results obtained from a selection index computer program (SELIND*). The results from selecting on several different combinations are expressed as a percentage of the theoretical improvement from selecting for fat yield with no restrictions on changes in other traits.

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*SELIND is a computer based selection index program developed by E.P. Cunningham

Table 6.2 Theoretical genetic improvement possible per year when selecting on particular traits for Friesian cows

Selecting for	Response to selection per year				
	Milk (litres)	Fat (kgs)	Protein (kgs)	Fat (%)	Protein (%)
Milk yield	<u>78.8</u>	2.4	2.3	-0.01	-0.01
Fat yield	62.2	<u>2.8</u>	2.2	0.01	0.00
Protein yield	69.7	2.6	<u>2.8</u>	0.00	0.01
Fat percent	-26.5	0.07	0.24	<u>0.05</u>	0.02
Protein percent	-24.3	0.40	0.69	0.02	<u>0.03</u>
Mean	5417	211	183	3.8	3.3
Coefficient of variation (%)	14	14	13	8.1	5.2

(Direct responses are underlined)

Table 6.3 Results from using a selection index on milk, fat and protein where improvement achieved when selecting for fat is the base case

Selecting for	Restrictions	Improvement (%)
Fat yield	None	100
	Milk yield	86.2
	Milk and protein yield	66.5
Fat and protein yield*	None	93.2
	Milk yield	80.9

*Equal selection weighting put on fat and protein yield.

The values given in Table 6.2 are for the theoretical improvement possible per year from a conventional progeny testing scheme. (Progeny testing is where an animal's performance is judged by its offspring and is normally the selection method used for traits expressed in one sex - such as milk production). In percentage terms, the improvement is in the region of 1½% of the population mean per year.

Smith (1984c) quotes examples relating to the improvement possible in various livestock populations. The value quoted for improvement in dairy cattle milk yield is 2.2% per year. This was achieved under experimental conditions using artificial insemination sires. In practice, the improvement registered was only 1% (from breeding programs in the United States). The commonly accepted level of genetic improvement achieved in the U.K. dairy sector is in the region of 0.25-0.5%, although O'Connor (1984) mentions values of 0.7-0.8% per year.

For the most part of this evaluation, the improvement levels in Table 6.2 will be used. Reference will be made to the figures in Table 6.3 where necessary.

6.3 Estimation of the benefits of improvement of production characteristics

In Chapter 5, four of the demand profiles examined demonstrated that, under present cost conditions, the theoretical optimal national herd should include breeds other than the Friesian and Holstein. In the analyses conducted, the required additional breed was the Jersey.

As an alternative to breed substitution, there is the option of changing the current production profiles of the existing breeds to fit the needs of the market better. The trait that appears to require improvement in the above-mentioned demand profiles is fat yield. Table 6.4 shows the total percentage increase in Friesian fat yield necessary for the theoretical optimal herd structures to be 100% Friesian. These values do not constitute the percentage change necessary in a single period, but the total change necessary, prior to any of the periods for the optimal herd to be 100% Friesian.

The values in Table 6.4 were obtained by adopting the assumption that there would be no change in either the costs of production or the penalties for overproduction of other traits, and that the improvement would only affect fat yield.

Before attempts are made to remedy some of the faults with the values in Table 6.4, it is interesting to note that the values represent the total percentage change in Friesian fat yield. Improvements in Friesian fat yield of only 2.3, 4.2 and 4.8% for the first three profiles in Table 6.4 would be all that would be necessary for a 100% Friesian herd to be as economic as the optimal structures in Table 5.10.

If these smaller improvements were carried out, the theoretical optimal structure would still be a Friesian/Jersey mix. This raises the quandary of whether, given a change in demand of the level suggested, producers would adopt a policy of optimisation and move towards a Friesian/Jersey mix, or undertake breed improvement of the order suggested in Table 6.4. A third option would be for the producers to adopt a policy of satisficing - i.e. just improving the Friesian fat yield enough for it to be as economic (assuming constant costs) to have 100% Friesian as against the combination suggested in Table 5.10.

Table 6.4 Percentage increase in Friesian fat yield for optimum herd of 100% Friesian

		Demand Profile			
Milk	(mn litres)	15212	13690.8	13690.8	10448.0
Fat	('000 tonnes)	654.5	654.5	654.5	595.0
Protein	('000 tonnes)	465.3	517.0	465.3	349.4

Period	Percentage improvement			
1	5.0	5.0	5.0	5.12
2	5.75	5.75	5.75	5.50
3	6.50	6.50	6.50	6.40
4	7.25	7.25	7.25	7.30
5	6.0	6.0	6.0	5.70

Unfortunately there is a lack of information readily available regarding changes in the costs of production when altering yields through either genetic or nutritional means in commercial herds. This restricts any in-depth analysis. One way around the problem could be to carry out an analysis, including provision for improvements in yields, but leaving the costs of production unchanged. The sensitivity of these costs could then be examined.

In the single period analysis, allowing for an overall increase (over a number of years) of 7.3% in the Friesian fat yield, the most sensitive area is the costs of production. The value 7.3% was chosen as being the minimum overall improvement in fat yield necessary for the optimal structures of the four demand profiles in Table 6.4 to be 100% Friesian. Assuming all other costs remained constant, the cost of producing with Friesians would only have to rise by 3% at this improved level of fat yield, for the optimal national herd to include the Jersey breed.

When discussed in the context of the multi-period analysis, the optimal national herd structures for the first three profiles in Table 6.4 are identical. Ayrshires and Holstein are almost completely replaced, Jersey numbers remain unchanged, whereas the number of Friesians producing actually drops. In percentage terms, however, Friesians would account for a larger proportion of the national herd.

The costs of producing with Friesians would have to rise by 8.7% as a result of either genetic improvement or dietary adjustments, relative to the costs of producing with other breeds, for there to be any significant change in the optimal basis. Considering this in the context of the multi-period model, an increase of 8.7% in the costs of producing with Friesians would result in Ayrshires taking an increased role in the national herd.

This information ought to be considered in conjunction with the results from the sensitivity analyses for the first three profiles in Table 6.4 - prior to any changes in Friesian fat yield. The output from the parametric analyses shows that increases in the costs of producing with Friesians would only have to be of the order of 7.5% in period 3, and 2% in period 5 (other breed production costs remaining unaffected) for Ayrshires to play a larger role in the national herd.

The second stage of the analysis of the potential benefits from improving the output of the Friesian is to consider what effect a change in the relative prices paid for the three products would have upon the optimal national herd structure. Such a change would be likely to come about as a result of a significant change in demand.

With the way the model is structured, this analysis could most easily be effected by taking the converse approach, namely to examine the consequences of changing the penalties for overproduction of the less important products. In the four profiles highlighted, this would entail examining the sensitivity of the penalties for overproduction of liquid and protein - the principal product being fat.

Results from sensitivity analyses conducted suggest that the optimal bases are reasonably immune to realistic increases in the penalty for overproduction of protein. Changes in the penalty for excess liquid production, however, are not so great.

Without any change in the Friesian production profile, the penalty for overproduction of liquid would have to increase to 17p per litre before the variables in the optimal basis are changed. At this level of penalty, Ayrshires would enter the national herd, because of their lower output of liquid, replacing some of the Friesians and Holsteins. With the penalty for liquid at this level, the Friesian herd becomes more sensitive to changes: production costs of Friesians would only have to rise by 1% (with other breed costs remaining constant) in years 3 to 5 for changes to be required.

When both factors are included in the evaluation (the penalty for overproduction of liquid rising to 17p and an overall improvement in Friesian fat yield by 7.3%) for the four demand profiles in Table 6.4, the costs of producing with Friesians becomes quite robust, requiring changes of just under 15% before adjustments occur in the optimal basis. For there to be significant changes in the number of each breed, costs of producing would have to increase by about 27% relative to the other breed's costs.

Table 6.5 shows the results from multiple single period analyses when the penalty for surplus liquid is 17p per litre. The analysis was carried out on the first three profiles from Table 6.4. The figures shown are:-

- the costs of production, including an increase in liquid penalty, but with no change in Friesian production levels;
- the percentage change in Friesian fat yield necessary for the costs of producing with an all Friesian herd to be equal to that of the calculated theoretical optimum (shown in column 1);
- the percentage change in fat yield necessary for the theoretical optimal basis to be 100% Friesian;
- the resulting costs of production from a column 3 change in the Friesian fat yield.

The figures in brackets for the third profile in Table 6.5 are the levels of improvement in protein yield, which along with the improvement in fat yield, is necessary for the

TABLE 6.5 Percentage increases in Friesian fat yield for national herd to be 100% Friesian.

(Penalty for liquid overproduction at 17p per litre)

		1	2	3	4
		£	%	%	£
Profile no.12	Period 1	1.73	5.9	10.9	1.54
Milk 15212 mn litres	2	1.63	5.8	10.1	1.4
Fat 654.5 thousand tonnes	3	1.54	5.8	9.7	1.39
Protein 465.3 thousand tonnes	4	1.45	5.7	9.4	1.32
	5	1.37	5.5	9.1	1.35
	Total	7.72			6.96
Profile no.21	Period 1	1.73	12.2	18.5	1.51
Milk 13690.8 mn litres	2	1.63	12.2	18.7	1.41
Fat 654.5 thousand tonnes	3	1.53	12.2	19.1	1.32
Protein 465.3 thousand tonnes	4	1.45	12.3	19.5	1.23
	5	1.37	12.2	20.0	1.14
	Total	7.71			6.61
Profile no.20	Period 1	1.76	11.2	19.6 (18.1)	1.66
Milk 13690.8 mn litres	2	1.65	11.1	19.2 (17.7)	1.40
Fat 654.5 thousand tonnes	3	1.56	11.1	19.6 (18.1)	1.31
Protein 517 thousand tonnes	4	1.47	11.3	19.7 (18.3)	1.24
	5	1.38	11.8	19.5 (18.0)	1.16
	Total	7.82			6.77

Notes:

Col 1. Cost of production plus penalties (£000M) - with no change in fat yield.

Col 2. Percentage change in Friesian fat yield for 100% Friesian national herd to be equal to column 1.

Col 3. Percentage change in Friesian fat yield for theoretical optimal to be 100% Friesian.

Col 4. Cost of production plus penalties (£000M) after column 3. change in fat yield optimal national herd structure to be 100% Friesian. These values were calculated on the basis that, when selecting for fat yield, the correlated response in protein yield is around 80% of fat yield improvement. If protein yield was not improved for this particular profile, the theoretical optimal structure would be a Holstein/Jersey mix.

It should be clearly stated at this stage that the percentage improvements necessary, which are shown in columns 2 and 3 of Table 6.5, do not refer to the results from a single period's selection and improvement work. The values refer to the total level of improvement required from a number of years improvement and selection work.

For the optimal herd structure to be 100% Friesian for the fourth of the profiles in Table 6.4,a total improvement in fat yield of 18.5% would be required. From the figures in Table 6.5 it can be seen that if at the time of the change in production circumstances, the ability to alter fat yield exists, reasonable savings in the overall costs of production can be made. For an improvement of just over 10% in fat yield, costs over 5 years for the first demand profile would be reduced by 9.85%.

The basis of this last section has been an analysis of the benefits of improvement of certain production characteristics of the Friesian, such that, for certain possible demand profiles, the optimal herd structure is 100% Friesian. This analysis has however excluded certain 'factors'. The next stage of the evaluation and comparison of breed substitution and breed improvement is to look at the costs that for a variety of reasons have been excluded from the models.

6.4 Additional costs of breed substitution and breed improvement

The benefits of having a national herd comprising more than just the black and white breeds was highlighted in Chapter 5. Advantages of carrying out improvement in Friesian production characteristics was demonstrated above for several different demand profiles. Both sets of analysis excluded costs which would be incurred depending on whether the policy adopted was breed substitution or breed improvement.

6.4.1 Breed substitution

For some of the demand profiles examined in Chapter 5 the optimal herd structures included Jerseys. One extreme profile suggested an optimal structure of 100% Jersey. Taking this last profile (milk demand 10448 mn litres, fat 595 thousand tonnes, and protein 517 thousand tonnes), it is interesting to compare what additional costs would be incurred as a consequence of such a national herd against a UK herd of all Friesian.

In 1982, the UK dairy herd supplied 63% of the home produced beef. The total value of UK produced beef for that year was just under £1700m (C.S.O. 1983). Culls of adult dairy cows accounted for 17% of the supply, with steers, heifers and bulls making up the other 46% (Southgate (1984)).

Making reference to the figures in Table 6.6, having a national herd of 100% Jersey would result in an increase in the actual herd size, which in turn would, after a period, increase the availability of animals for culling. Taking

TABLE 6.6 **A comparison of an all Friesian herd and an all Jersey herd for demand profile number 29**

	100% Friesian	100% Jersey
Adult herd size	2.8 m	3.02 m
Culls from dairy herd (thousand head)	564	604
Average weight/cow (kgs)[2]	540	325
Average value (£)[3]	320	160

Notes:

1. Culls set at 20% of the adult herd

2. Source - MLC - Personnal Communication

3. Source - MMB Economics Division 1980

into consideration the current average weight per cull cow, however, there would in fact be a decrease in supply of around 100 tonnes liveweight. This would amount to a reduction in income to dairy producers as a whole of just under £100m for a single year. This does not include the consequences with regard to dairy bred calves sold to the beef sector.

In addition to the above mentioned cost to producers, costs would be incurred during any transition period. The type of costs that would arise include the cost of additional housing facilities for an increased herd size and the cost of having to replace existing breeds. The extent of these costs would depend upon the degree of change required.

Taking the figures calculated above for the cost to dairy producers of a 100% Jersey breed, and comparing it with the potential benefit from having an all Jersey herd for the demand profile number 29 in Table 5.9 (milk demand 10448mn litre, fat 595 and protein 349.4 thousand tonnes) of £590m over 5 years (Table 5.11), the net benefits are low. The £90m difference over the 5 years does not include the transition costs. If, however, the penalty for overproduction of liquid rose from 3p per litre to 17p, the potential net benefits over the 5 year period would rise to around £3 bn.

6.4.2 Breed Improvement

The additional cost from maintaining a herd of 100% Friesian for the demand profiles tested is primarily the cost of carrying out an intensive breeding and selection programme. In theory it could be said that the cost of operating an improvement and selection scheme was simply the lost income from keeping the nucleus herds (in which most of the improvement would be achieved) as against a fully commercial herd, plus any additional testing costs. Smith (1985) calculated the cost of keeping a herd to develop alternative genetic lines at just over £10,000 per year per line.

In addition one ought to consider the costs incurred by the Milk Marketing Boards for their progeny testing schemes. The cost of the Dairy Progeny Testing Scheme (DPTS) over the last couple of years has been in the region of £500 thousand per year, and has involved testing betwen 100 and 140 bulls, and just over 40 thousand females (Personal Comm MMB). As a result of the DPTS, it is believed that the improvement achieved has been between 0.7 and 0.8 per cent of the population mean per year (O'Connor,(1984)). In all probability, no matter which of the two policies were adopted (breed substitution or breed improvement) some form of progeny testing would be carried out.

6.4.3 Additional costs applicable to both policies

The additional costs for both breed substitution and breed improvement which were not included in the earlier analysis relate to the adoption of the possible alternatives. Achieving the optimal structures using either of the two possible policies will take time. Looking at Table 6.2, the theoretical genetic improvement per year is around 1.5% of the population mean. Improving the fat yield with restriction on either milk or milk and protein reduces the level of improvement possible, as can be seen in Table 6.3.

To switch from one breed to another using normal substitution methods is comparatively slow. If one adopts the option of cross-breeding, and aims for a total population comprising of a proportion of Friesian genes, with Jersey genes making up the remainder, substitution time decreases.

Table 6.7 shows the intervals required to achieve the necessary improvements for the four demand profiles highlighted earlier. The values allow for crossbreeding for the breed substitution option, but do not take into account the rate of acceptance of the improved stock, or the speed at which producers would switch to Jerseys.

The figures shown in Table 6.7 were calculated by taking the level of improvement in fat yield necessary for each profile from Table 6.4 and 6.5, and the theoretical percentage genetic improvement to obtain the minimum theoretical lag time. Two values were calculated, representing the substitution times necessary for when the penalty on overproduction of liquid was 3p per litre (A) and 17p per litre (B). The value used for the theoretical genetic improvement was 0.93% of population mean per annum. Breed substitution lag times were calculated using the values from Table 5.11 and worked on the assumption that if 100% of the Friesian producers mated their cows to Jersey bulls, the resulting herd would be 50/50 Friesian/Jersey. If this generation was then mated to pure Jersey bulls, the resulting generation would be 25/75 Friesian/Jersey, and so on until the required proportion of Jersey genes had been attained.

The breed substitution lag could be reduced using the techniques of multiple ovulation and embryo transfer (MOET) - providing there was a sufficient suitable supply of donors. The cost of operating such a scheme on the level that would be required is difficult to quantify. Smith (1984b) calculated the cost of collecting and storing

TABLE 6.7 A comparison of theoretical improvment lags for breed substitution and genetic improvement.

Demand Profile	LAG Breed Substitution (years)	Genetic Improvement (years) A	B
Milk - 15212 mn litres Fat - 654.5 thou. tonnes Protein - 465.3 thou.tonnes	5	8	12
Milk - 13691 mn litres Fat - 654.5 thou. tonnes Protein - 465.3 thou.tonnes	10	8	22
Milk - 13691 mn litres Fat - 654.5 thou.tonnes Protein - 517 thou.tonnes	10	8	17
Milk - 10448 mn litres Fat 595 thou.tonnes Protein - 349.4 thou.tonnes	20	8	20

Notes:

A. Improvement lag for genetic improvement of fat yield when the penalty for overproduction of liquid is 3p per litre.

B. Improvement lag for when the penalty for overproduction of liquid is 17p per litre.

embryos from 25 donors as being around £75,000. This cost does not include the cost of implanting the fertilised embryo into the recipient cow.

The rate at which an innovation or improvement is adopted by an industry is usually regarded as following an S-curve pattern (Twiss(1980)). Griliches (1960) attributed the rate at which people adopt a new technique or product as being dependant upon (amongst other things) their perception of the improved benefits from having the new product. Gold (1977), however, questions this and suggests that factors such as the potential innovators' perception of possible operational uncertainties should be considered.

Estimation of a possible rate of adoption in the context of this research is difficult simply because there is no similar occurrence to use as a guide. A comparison of sorts could be made with the uptake of artificial insemination (A.I.) by cattle producers in the U.K. in general, or with the increase in use of a specific breed introduced into an otherwise 'closed' population.

The values for the use of Charolais semen as a percentage of total U.K. insemination and total insemination using beef bulls are shown in Table 6.8 As can be seen by these values, the initial sharp increase in the use of Charolais semen was halted in 1974/75. This fall was partly due to the realisation that Charolais calves were prone to cause calving difficulties. Around this time, however, there was also a drop in the total number of inseminations using A.I.

A conclusion that can be drawn from the above figures is that the value of applying estimates for the rate of adoption of each of the possible options tested earlier is not really worthwhile. The area more worthy of discussion is whether or not, given the range of possible profiles

TABLE 6.8 **Use of Charolais semen in the U.K. as a percentage of total beef inseminations, and total U.K. inseminations.**

Year	Charolais as a percentage of	
	Beef Herd	UK Total
1968/9	15.1	4.8
1969/70	14.5	5.5
1970/1	14.8	5.7
1971/2	14.9	5.4
1972/3	16.9	5.5
1973/4	19.3	6.9
1974/5	15.9	6.2
1975/6	14.5	5.3
1976/7	15.5	5.2
1977/8	16.5	5.5
1978/9	19.4	5.9
1979/80	19.7	6.7
1980/1	20.1	7.2
1982/3	19.3	6.3

that could arise, producers would optimise by changing the breed structure of the national herd or by improving the dominant breed.

If producers as a whole decided against changing the breed composition, moves could be made, in most instances, to cut the level of production for the less desired product(s) by altering the diets as a short term measure. If, for example, the penalty for surplus liquid production did rise to 17p per litre, with all other costs and characteristics staying constant, liquid volume would need to fall by 9% for profile number 12 (see Table 5.9), 17% for profile number 20 and 18% for number 21 to achieve the same overall production costs (i.e. including penalties) as altering the breed composition of the herd. Some of this reduction could be achieved by reducing the level of concentrate feed. This happened in 1984, when, following the annoucement of milk quotas by the European Community, dairy producers cut back their use of concentrates (Pers. Comm - SMMB).

This area raises the question of how individual producers would react. Drawing upon the reactions of producers to recent events, their actions would appear to depend upon their perceptions of the net benefits from changing, the current status of their herd (both physical and financial) and their willingness to adapt. The recently required cuts in milk output were achieved by a combination of some producers reducing their concentrate feed usage whilst others reduced their herd size. Some producers took the reduction in herd size a step further and left dairy farming altogether.

Information from previous attempts to reduce supply, instigated by the EC, suggest that some of the producers who ceased production altogether were not representational of the norm. In schemes designed to encourage producers to either not sell their milk or convert to other forms of agriculture, the producers that took full advantage of the subsidies and other payments were operating with low yielding animals, in herds well below the average size. Applying this premise to the 1984 cuts, the producers remaining in the national herd would be those operating larger herds; with the Friesian and Holstein breeds faring best.

Dietary changes could be sufficient to meeting fluctuations in demand in the short term, but, as a long term solution they raise questions concerning efficiency of production. This,therefore, leaves the problem of whether, for any long term correction needed, producers should look towards genetic improvement or breed substitution.

6.5 Breed substitution versus genetic improvement

The advantages of both options have been discussed to some length. The emphasis so far, however, has been on discussing both options separately, and making no comparison of the two. Probably the best method of achieving a comparison is to discuss some of the problems associated with adopting either of the policies.

The main problem with the breed substitution option is that, for the costs and yields used in the analysis, breeds other than Friesian and Holstein would only really appear to be required if the demand for fat rose significantly, with the demand for other products staying either constant or decreasing. For proportionally high protein demand profiles, the optimal breeds would appear to be the Friesian and Holstein - for example the extreme profile tested in Table 5.12 (ii). Genetic improvement and selection work could be carried out on Friesian production characteristics to suit profiles with either high fat or protein requirements.

A further important problem with breed substitution as a national alternative would be convincing producers of the benefits of changing. Re-examining the information in Table 5.10, switching to a mixed Jersey/Friesian herd from one of 100% Friesian for profiles 12, 20 and 21 would only result in a drop of total costs of 3.0%, 5.0% and 5.4% respectively over the five year period (assuming that the overproduction penalty for liquid stayed at 3p per litre). This drop in costs does not include the loss in either the initial stages (i.e. an increase in Friesian cull cows causing a reduction in the usual sale price) or once the Friesian/Jersey mix had been completed (Jerseys having a lower cull cow value). Including this factor, the drop in costs would be even smaller. Excluding the matter of lost beef sales revenue, the total level of improvement of Friesian fat yield necessary for an all Friesian national herd to be **as economic** as the breed mix option for the three profiles mentioned is, at most, just under 5%

The disadvantages with genetic breed improvement relates to the combined facts that the figures quoted in the above paragraph relate to the situation where the penalty for surplus liquid remains unchanged, and that the annual improvement levels that have been used in the calculations are the **theoretical maximum** levels. The actual level of improvement achieved in the U.K. in the past has been much less.

If the penalty for overproduction of liquid rose to 17p per litre, the cost difference between a national all Friesian herd (with no genetic improvement) and a Friesian/Jersey mix for profile number 20, would be 23% over the five year period. The genetic improvement lag for this profile (assuming an actual improvement of 75% of the theoretical level) would be almost 17 years for the cost of the all Friesian herd to be equal to the mixed herd.

Taking an extreme case (liquid demand 13691mn litres, fat and protein demand 141 and 564 thousand tonnes respectively - 1% and 4% of liquid), the theoretical optimal in period 1 would be 100% Friesian when the penalty for liquid surplus was 3p per litre. Increasing the penalty to 17p per litre, the optimal becomes 100% Jersey. For Friesian to be the optimal breed at this level would require a 9% improvement in Friesian protein yield.

The problem of deciding between breed substitution and genetic improvement would, therefore, appear to be largely dependant upon how one views the pattern of demand will change and what would be the associated changes in the relative prices of the products.

With regard to demand, it could initially appear to be very unlikely that if the current demand profile were to change dramatically it would be to one with a proportionally high demand for fat. Recent trends suggest that people are moving to a diet containing lower animal fat over fears of the level of cholestrol intake. Figures in Table 6.9 show the decline in milk and butter consumption per head, but a gradual increase in margarine (which contains vegetable oils).

The apparent exception would appear to be a change in emphasis at the milk distribution stage as described in the second half of Appendix A. The change mentioned is where the actual requirements for manufacturing purposes of liquid, fat and protein are calculated and the emphasis is on the supply of each rather than total liquid volume. Using such an approach would appear to cut down the surplus of skimmed milk.

TABLE 6.9 U.K. per capita consumption of selected products

	Liquid milk (litre per head per annum)	Butter	Margarine
		(Kgs per head per annum)	
1970	137.2	8.8	5.4
1971	135.1	8.2	5.9
1972	135.0	7.2	6.3
1973	136.5	7.6	5.8
1974	139.5	8.3	4.9
1975	142.3	8.4	5.0
1976	140.4	8.3	5.8
1977	135.3	7.8	6.5
1978	133.4	7.5	6.3
1979	131.9	6.8	6.5
1980	128.9	6.3	6.9
1981	126.8	6.0	7.1
1982	124.9	5.8	7.3

(source: MMB Dairy Facts & Figures)

6.6 Discussion

The discussion has so far centred around the assumption that once a change in demand had occurred, moves would then be made to alter the national herd. A major cost incurred with this operation which has not been discussed, is the losses incurred whilst changes are being made to the herd. The losses could amount to either increased imports or subsequent loss of market through failing to meet the consumers demands, or increased subsidies, grants or incentives to producers to try to reduce surpluses.

One method of reducing this cost would be to reduce the time taken for the changes to the breed to be implemented fully. With the breed substitution option, this would require a major programme of MOET. Such a programme would be costly, and would depend on the availability of suitable donors. Reducing the time lag for the genetic improvement option would require the existence of a number of different possible genetic lines. In relation to the traits used in this analysis, possible examples could be high fat, or high protein, or low fat or low protein producing Friesians. If the different lines were stored in the form of semen, storage costs would be minimal.

The expense involved with storing a number of alternative Friesian lines would be the cost of the selection work necessary to identify suitable sires. The cost of this, as already mentioned, could be around £10 thousand per year for each line (Smith(1984a)). The dissemination of the improved stock, when necessary, into the national herd would be comparatively straightforward using the channels currently available (i.e. the A.I. service provided by the Milk Marketing Boards.)

With regard to the level of subsidy or incentive that would be needed (if any) to encourage producers to change the only comparison that is available relates to a scheme operated by the European Community. In May 1977 the European Parliament introduced a system of payments for the non-marketing of milk and milk products and for the conversion of dairy herds to try to reduce the growing community surpluses of certain dairy products. Up to the end of December 1981 there had been just over 8 thousand applicants from the UK for the scheme, offering to withdraw 326 thousand cows. The costs for the UK withdrawals amounted to just over £193m over a 5 year period - or just over £591 per cow withdrawn (Of.J of the EC).

It is difficult to say how effective the scheme was, and thereby give some sort of estimate at the required level of incentive for the instances examined. However, it is worth noting that the European average cost for withdrawal was 441 Units of Account per cow, whereas the UK average cost was only 366 Units of Account. The average milk yield per cow withdrawn from the UK by this scheme was around 4144 kgs, whereas the UK average yield for dairy cows in 1981 was 4908 kgs (5486 kgs for cows in herd involved in milk recording schemes). The implication of this is that the producers who took up the premium were not from the large Friesian herds.

A direct comparison with these costs is not really possible in that the requirement for the profiles examined would not be to remove producers but to encourage them to change sooner. A combination of an increased penalty for excess production along with some form of subsidy to offset the costs of adjustment would appear to be the best solution. In the event of such a decision, the rate of change by producers would be directly dependant upon the severity of the penalty.

A criticism that could be levelled at this analysis is that biological efficiency has been ignored. Being a believer of Newton's first law of thermodynamics, it is not really valid to assume that one can alter the output of an animal by genetic means without affecting some other characteristic of the animal. For the purposes of this analysis, it has to be assumed that improving the output from the animal does not adversely affect its overall value.

Biological efficiency could also have been discussed in a slightly different context to that mentioned above. Currently the value of a cow is measured in terms of its output of milk and the value of its calves and (ultimately) its own carcase value. With concern currently growing over the level of milk and milk product surpluses, perhaps greater emphasis should be put on the efficiency of production. For example, the measure of efficiency could take into account factors such as the calorific value of the feed required to sustain the desired level of output.

6.7 Conclusion

This chapter has taken the results obtained from the multi-period analysis in Chapter 5, and compared them with achieving the necessary changes through genetic improvement and selection. Adjustment of production levels by dietary means was briefly examined, but excluded from the main analysis on the grounds that there is no cost information available from commercial herds.

In the detailed analysis, four of the demand profiles highlighted in the previous chapter were examined to determine the level of improvement required in the three production traits for the dominant breed to remain Friesian. As well as the change necessary for optimality, the analysis included the level of improvement needed for an all Friesian herd be be as economic as for the breed substitution option. With no changes in the costs used in the linear programming model, the maximum level of total improvement required was only 7.3%.

The next stage of the analysis in this chapter was to increase the penalty for overproduction of liquid, and examine the effect on the level of improvement required for the optimal structure to be 100% Friesian. The chapter went on to examine some of the costs excluded from the earlier analysis for both the breed subsititution and genetic improvement option.

The outcome from the analysis of the selected profiles is that for the figures, relationships and assumptions used in the evaluation, genetic improvement of the current dominant breed is the better option. The proviso to this conclusion is that a stock of the necessary genetic material is available in a form that can allow the improvement to be transmitted into the commercial herd.

Breed substitution, although appearing a viable proposition in certain circumstances has the disadvantage in that major breed changes will have consequences outwith the dairy sector. Where it has a slight edge over genetic improvement is where changes occur in the demand profile for which a genetic line is not available. In such circumstances, if desired by producers, a compromise breed structure could probably be arrived at from the existing breeds available. The output from these existing breeds could be adjusted to a certain extent by nutrititonal means.

The overwhelming impression obtained from this analysis is that the degree of change achieved within the national herd would be dependant upon the incentives offered, in particular the penalties imposed for excess production.

CHAPTER 7 Discussion

7.1 Introduction

In chapters 5 and 6 a series of possible demand profiles were examined to try to quantify the benefits from having diversity in the UK dairy herd. Attention focussed on the value of maintaining breed diversity, as against the benefits from having gene diversity accessible to the commercial herd. The outcome from the analysis was that, for the situations examined, there would appear to be little requirement for breed diversity, if gene diversity is readily available, facilitating genetic change of the dominant breeds.

The purpose of this chapter is to look at this conclusion and discuss it in a broader context. Initially, the discussion will examine the situation that has occurred in the dairy sector since this research was started, examining the consequences of the quotas on milk production introduced by the European Community Agriculture ministers. The final stage of the chapter will be to discuss the conclusion from Chapter 6 in the context of other sectors and emerging technologies.

7.2 Recent events in the UK dairy sector

Since the main part of this evaluation was completed, a system of 'super-levies' has been introduced in the UK following the imposition of quotas by the European Agriculture ministers in 1984. The system was introduced as a result of the growing concern over the mounting surpluses of dairy products within

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7.2 Recent events in the UK dairy sector

Since the main part of this evaluation was completed, a system of 'super-levies' has been introduced in the UK following the imposition of quotas by the European Agriculture ministers in 1984. The system was introduced as a result of the growing concern over the mounting surpluses of dairy products within the European Community. The basis of the levies has been to penalise individual producers who exceed a given quota for liquid production.

At the time of introduction, the total production of milk expected from the EEC countries for 1984 was in the region of 108m tonnes (20m tonnes above the total demand). The initial aim was to reduce total Community production by just under 8%. The UK was expected to cut production by about 6.5% of 1983 production levels (Sutherland (1984)), amounting to just under 1070m litres.

Of particular interest to this research is how producers coped with the change in circumstances. Table 7.1 shows figures for average milk yields, the production of concentrate cattle feeding stuff and cattle numbers to the end of 1985. From these figures it can be seen that milk yields have fallen from a high in 1982. Latest figures suggest, however, that yields are increasing again. Production of concentrate feed for cattle seems to have fluctutated, but output for 1984 and 1985 was appreciably lower. In comparison with levels for several years prior, the number of cattle slaughtered in 1984 increased slightly. Cow and bull culls accounted for 45% of this increase.

The conclusion that could be drawn from the figures shown in Table 7.1 is that the required changes in output were met by a combination of a reduction in numbers and a decrease in the use of concentrate feed. What confuses the situation, and is not shown in the table, is that the weather in 1984-85 was not good for dairy producers. The combination of a hard winter and wet summer resulted in lower dairy yields, and at one stage it actually looked as if the quota levels would be met without the need for penalties.

One conjecture that could be made from the figures is that yields generally were depressed by a combination of adverse

Table 7.1 Yield, Production of cattle feed and cattle numbers from 1976

	Yield[1] (litres per cow)	Production cattle feed[2]	Cattle slaughtered[2] (thou tonnes)	Dairy Cattle[3] in milk	Dairy Cattle[3] in calf (thousands)
(thousands)					
1976	4275	395	373	2909	323
1977	4545	371	343	2937	331
1978	4650	376	336	2958	316
1979	4670	411	338	2975	317
1980	4760	380	355	2938	290
1981	4745	378	337	2907	284
1982	5055	417	302	2984	266
1983	4940	454	325	3058	274
1984	4725	365	356	2977	303
1985	4900[4]	345	348	2882	268

Notes:

1. Yield figures relate to an April-March year.
2. Monthly averages.
3. Cattle on agricultural holdings in June.
4. Provisional estimate from MMB

weather conditions and a reduction in concentrate feed usage. Perhaps the reported average yield figures have remained comparatively buoyant in the light of these changes because of a significant shift in the breed mix of the national herd - namely the proportion of Friesians and Holsteins increasing. Unfortunately sufficient data to prove (or disprove) this hypothesis is not currently available.

It is evident, however, that the full impact on the UK dairy herd of the introduction of quotas will not become clear for a while. Looking at the yield figures for 1983 and 1984 shows that yields dropped by around 4.4%. For the same period, however, expenditure per cow on purchased feeds dropped 25% *. What needs to be ascertained is whether the UK dairy herd breed composition changed significantly over the period and whether there are any discernible patterns in the breed and average age mix of the additional cattle culled in 1984 and 1985.The whole subject of milk quotas raises the interesting point of whether the impact of the introduction of constraints on output could have been lessened if the correct form of diversity was available at the time. The result required by the agriculture ministers appears to have been an immediate reduction in output - this could only be achieved by reducing the total herd size and/or dropping yields. In the event, as mentioned, UK producers used both options. Having additional diversity available would have made no difference simply because of the lack of time available to make any adjustment.

What about the situation in the longer term? Average milk yields in Europe before the quotas had been on the increase - yields in the Irish Republic rose by 41% between 1970 and 1982, whereas the average increase in Europe was just under 25%. By all accounts yields would have continued to increase if quotas

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*Milk Marketing Board figures show that between 1983/84 and 1984/85, the average level of expenditure on purchased feeds dropped by about £70 per cow had not been introduced. To allow yields to continue to increase (as the latest estimate from the MMB shows they are) and to avoid incurring penalties, either the average herd size will have to drop, or further producers will have to leave the dairy sector. A drop in individual herd size would result in an increase in the fixed costs per cow, whereas further cuts in the size of the national dairy herd could result in some farmers going into other areas of agriculture where there are already problems with surpluses.

Alternatively the dairy sector as a whole could re-evaluate its style of production, switching its main emphasis in choice of breed from volume to some other production characteristic.

7.3 The Community Agriculture Policy - a real need for diversity?

In chapter 3, diversity was justified on the grounds of the benefits from a 1% increase in total output. The discussion here will consider whether the availability of genetic diversity could be beneficial to the current situation within the European Community, where concern is growing over the increasing stocks of surplus agricultural produce.

From 1977 to 1982, 816.4 million E.U.A.* (approx £505m) was spent on attempts to reduce the number of dairy cattle in the Community and the amount of milk sold (Bulletin of E.C.(1983)). In 1982, agriculture expenditure, amounting to 12991 million ECU (about £8037m), accounted for 64.9% of total EEC expenditure. Of the total agriculture expenditure, 25.6% was spent on milk and milk products. The actual breakdown of expenditure can be seen in Table 7.2. Approximately £1310.9m

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*European Unit of Account: the EUA is similar to the European Currency Unit (ECU) in that its value is determined by a weighted basket of currencies.

Table 7.2 Expenditure of the European Agricultural Guidance and Guarantee Fund on milk and milk production 1982

	million ECU *
Export refunds	1521
Storage of skim milk powder	135
Aid for skim milk and powder for animal feed	1067
Aid for skim milk processed into casein	243
Storage of butter and cream	197
Aid for butter	414
Intervention for other milk products	63
Other measures	225
Financial contribution by milk producers	-537
Total	**3328**

* £1 = 1.61641 ECU

(Sources: EEC Dairy Facts and Figures (1983), MMB) of the total shown was spent on subsidising surplus production in the form of either aid or storage costs. This amount was spent despite community production far exceeding requirements for certain dairy products (see Table 7.3).

Agriculture plays an important role in the economy of the European Community. In Greece, taking the extreme example, just under 30% of the total labour force was involved in agriculture in 1981, contributing just under 15% of the country's Gross Domestic Product. Figures for the Irish Republic are 15.9% and 10.9% respectively (MMB(1983)). Assuming an average yield in the Community of 4250 kgs per cow (MMB(1983)), to have achieved the required reduction in output (which amounted to approximately 8.5m tonnes) by a straightforward drop in numbers would have meant removing around 2 million cows from dairy production. Regardless of whether the cut was achieved by producers moving to beef production or simply culling the animals, the result would have been that, in easing the problem of surplus milk production, the problem of surplus meat production had been increased. In the longer term, one has to consider what the consequences of such cut backs could have on the levels of unemployment and general economies of the countries more reliant on agriculture.

What one therefore moves on to consider is whether a concerted effort should be made to encourage producers, throughout Europe,to adapt their patterns of production, and, if so, whether the availability of genetic diversity would assist the transition. As with the UK, the major breed within Europe is the Friesian, accounting for over 60% of all dairy cattle. To move away from the black and white breed in the short term would have repercussions outwith the production of milk, simply because Friesians produce calves suited for beef production. The extent of the consequences on meat production would depend upon the breed to which Friesian producers switched.

Table 7.3 Self sufficiency percentages of EC member countries for certain dairy products in 1982

	Butter	Cheese	Condensed milk	Powders whole & skim	Powders whey	Casein
	per cent					
Germany	128	101	149	209	122	100
France	124	119	230	1200	202	286
Italy	59	73	50	18		
Netherlands	343	238	358	916	66	
Belgium/Lux	107	44	30	182		
United Kingdom	72	70	123	413	124	100
Irish Republic	287	431		2050		633
Denmark	233	438	1100	500		350
Total Ten	**126**	**109**	**190**	**470**		**198**

(Source: EEC Dairy Facts and Figures (1983) MMB)

The alternative to moving away from the black and white type of breeds would be to either shift the emphasis in the selection programmes employed, or to adapt the husbandry techniques. The most obvious change in husbandry techniques that could be effected would be altering the diet. In England and Wales purchased feed cost accounted for just under 40% of total costs in 1983-84 (this figure dropped to 31% for the following year when quotas were introduced). Dairy producers in New Zealand, however, use minimal (if any) concentrate in the cattle diets. A comparison of yields for the Holstein can be seen in Table 7.4. It is interesting to note that although actual yields in New Zealand in 1981 were 1200 kgs per cow lower, the fat and protein content of the milk was higher.

To judge the potential benefit of a move away from concentrate feed usage requires more comprehensive cost information from commercial herds for various breeds. It would appear from the general data that is available that, although reducing the level of concentrate feed used depresses yield, the gross margin per litre improves.

The alternative to dietary changes is for producers to give greater consideration to characteristics aside from volume of output in their selection programmes. A range of possible alternatives exist,such as efficiency of production, with efficiency being measured in terms of input and output. The success of any such scheme, however, would very much depend on re-educating producers, ensuring that the benefits from any such move are visibly apparent to the farmers, and a readily available supply of the required genetic material.

Returning to the subject of the genetic diversity, however, it would appear that, in the case of milk quotas, there is no great need for additional diversity. There is already a diverse stock of material available (particularly when one looks outwith the UK) and a significant reduction in output could be achieved by non-genetic means. This does not mean

Table 7.4 A comparison of Holstein yields for 1981

	New Zealand	England and Wales
Milk (kgs)	4996	6295
Fat (kgs)	206	237
Protein (kgs)	180	202
	%	
Fat content	4.12	3.77
Protein content	3.60	3.21

(Source: Dairy Facts and Figures (1982), MMB & Rendell (1981)) that in general diversity is not required. The brief discussion above focussed on total volume; other needs for diversity still exist.

7.4 General discussion of the needs for diversity

Prior to concluding, attention will briefly shift to a more general level. The discussion will focus on the applicability of the conclusion that was reached in Chapter 6 to other agricultural sectors and the consequences of new animal breeding technologies that are emerging, but still at the experimental level.

In specific terms, the actual conclusion arrived at in Chapter 6 can only refer to the UK dairy herd. The results obtained were very dependent upon the figures used and the situations examined. The approach, however, could be applied to most other livestock populations, particularly those where one or two specialised breeds or strains are emerging. Examination of the potential benefits of diversity also need not be confined to either current domestic breeds, or the products presently regarded as important.

Efforts are being made to cross domesticated breeds of goats with certain feral strains in order to facilitate the controlled production and'harvesting' of cashmere wool which is at present only obtained from the feral breeds. Developments of this kind would be of particular benefit to rural communities not normally suited to recognised forms of intensive agriculture. The benefits from such an improvement would come in several forms: some producers could switch from sheep production, thereby helping to reduce the surplus of sheepmeat within the EC, as well as producing a required high value product. This particular development is facilitated by the availability of a source of genetic material from outwith the normal commercial population.

Diversity can also have benefits in areas different to those for which the animals concerned are kept. Dairy cows are kept to produce milk. Research is being undertaken to ascertain whether, through genetic manipulation, dairy cows can be used to produce factor 8 and factor 9 - human blood clotting agents. The usual source of these clotting agents is human blood. Quantifying the potential financial benefits from this work (if successful) would be difficult, and would depend on whether using dairy cattle to secrete these products was more efficient than the other avenue being explored - synthetic production of factor 8 by biotechnology. The advantages to medicine could, however, be immense particularly in the light of concern over the spread of Acquired Immune Deficiency Syndrome (AIDS).

Without some sort of diverse genetic reserve, research into new animal production techniques would be difficult. With milk yields having increased so much over recent years, the number of adult cows required to meet demand has declined - this in turn has reduced the stock of calves for both dairy replacements and beef production. Partly as a result of this, efforts are being put into increasing twinning in cattle. At present, natural twins are unusual in European breeds. If twinning could be achieved genetically, with a degree of predictability, response times to required changes in the breed structure could be decreased substantially, particularly when combined with embryo transfer.

Response times could also be improved if techniques of embryo sexing were successfully developed. Embryo sexing (when used with embryo transfer) would enable producers to plan their production profiles, giving them the choice of either producing females for breeding, or male stock for meat.

To this point the advantages from having increased flexibility through ensuring genetic diversity has only been discussed in the context of livestock: considerable efforts would appear to have already been put into preserving stocks of genetic material for plants, both in the UK and abroad. In the US, for example, a strain of wild maize was found to be immune to four diseases which affected commercial strains. Introducing the genes from the wild strain to the commercial strains could result in savings through reducing crop losses of $50m - $250m a year in the US alone (Prescott - Allen (1983)).

7.5 Conclusion

The aim of this chapter has been to step back from the specific analysis conducted in previous chapters and look at a number of areas. There are major areas which require considerable work before any further analysis of this kind could produce a definitive answer to the subject matter - for example detailed cost studies for different breeds using different diets. Despite the problems encountered, the results obtained in this research are not meaningless. The primary value of this work, however, has been in indicating the magnitude of the potential benefits from having some reserve of diverse material and in demonstrating a method of evaluating the problem.

Having discussed the recent events within the dairy sector, it is apparent that any further analysis of this nature should consider situations that could be brought upon UK dairy producers by external bodies. With concern mounting over the whole structure of the Common Agriculture Policy, it is only a matter of time before further significant reforms are proposed which would require producers to alter their production profiles. Ideally further analysis of the benefits of diversity should look at a range of possible solutions to the current dairy surplus problem aside from a simple reduction in numbers and consider the consequences each would have on the current structure.

During the analysis in Chapters 5 and 6, the attention focussed on the benefits of having diversity at a time when there was an imbalance between supply and demand. Although the evaluation processes were concerned with the possible situations within the UK dairy sector, the format used could have been employed within most agricultural sectors. In this instance, it was shown that the potential benefits from having diversity could be substantial. Where problems arise with this, and any other, form of economic analysis is when the primary benefit or outcome from the increased diversity is not easily quantified. Such an instance is mentioned above - the possibility of genetically inducing cattle to secrete human blood clotting agents.

In this example, although the products (if the project is successful) have a monetary value, many would consider their **actual** value as being greater. This is where the whole area of quantifying the benefits from having diversity becomes difficult. Of the projects and possible developments mentioned in the previous section, some would still be possible even if diversity was limited. For these projects the advantage of having greater diversity becomes the benefit of having an increased reaction time.

This research has only really considered the situation of **maintaining** diversity. To take the analysis further, and consider the needs for, and potential benefits of, **increasing** diversity would require a more detailed appraisal of possible future events and needs within the agriculture sectors. The problem with this sort of work would not only be in attempting to predict possible events, but also the prevailing economic relationships, particularly after any significant structural change. Such an analysis would be very subjective. It could be argued that sufficient diversity already exists - especially if one considers the situation from a world-wide viewpoint. Not only are there a wide range of breeds available, but there would appear to be a reasonable selection of strains within each breed group. What is not desirable, however, is for the current level of genetic diversity to decrease by any significant amount.

As already mentioned, it is not possible to predict future needs for diversity. At least by maintaining what already exists, there is a better chance of being able to match changes in breed requirements. Thanks to germ plasm storage techniques, the costs of maintaining diversity are relatively low compared with the potentially large benefits from having it available.

Chapter 8 Conclusion

There has been considerable discussion in recent years on the need for conserving genetic material from agricultural populations. The discussion has covered most aspects of agricultural production, and has considered the situation in both the developed and developing countries.

Concern in the developing countries has focussed on the efforts being made to improve agricultural production by introducing breeds and strains from areas such as Europe and North America, replacing the indigenous populations. Through this action breeders are running the risk of losing any immunity to local diseases and climate that could be present in the native breeds. In Europe and North America, the attention has been on whether, with the increasing tendency towards a single breed in some livestock sectors, the existing genetic base would be sufficient to allow for changes in the pattern or level of demand.

This piece of research has focussed on the situation within one specific agricultural sector and examined whether there is a need for genetic diversity. Attention has centered on the dairy herd within the United Kingdom, and has addressed the question of whether, if diversity is required, it should be breed or gene diversity. To assist in this analysis a linear programming model of the UK dairy sector has been developed. The model was designed to examine the effects different demand profiles could have upon the combination of breeds in the national herd. Total demand was expressed as a combination of the demand for liquid, butterfat and protein.

The outcome from the mathematical analysis was that for most of the demand profiles examined, the optimal herd structure was 100% Friesian and Holstein. (Friesians account for the major part of the UK and European dairy herds). The exceptions to this finding were the profiles which included a proportionally high demand for fat. In such cases, the optimal structures included Jerseys. For profiles where the demand for fat exceeded 5.1% of liquid demand, the optimal strucure for the national herd became 100% Jersey. The basis used for determining optimality was minimisation of production costs and the penalties for excess production.

In many of the cases examined, altering the breed structure of the national herd would have resulted in additional costs being incurred which were not included in the model. The additional costs related to the effect on beef production of dairy producers moving away from the Friesian breed. For this reason, the final stage of the analysis considered the genetic changes necessary in the production characteristics for the Friesian breed to be optimal in all cases examined.

The analysis of the level of improvement demonstrated that, as with the breed analysis, one of the most influential factors was the penalty imposed for surplus milk production. When the penalty was low, only comparatively small changes were required for Friesians to be the optimal breed. Under such circumstances, for the situations examined, the benefits of genetic improvement outweighed the option of adjusting the breed structure of the national herd.

Increasing the penalty for excess liquid production to 17p per litre, however, more than doubled the required genetic improvement, raising the necessary gain in fat yield for certain demand profiles up to around 20%. Further examination showed that if the prerequisite of optimality was dropped, at the increased level of penalty, improvement in fat yield of only just over 12% would result in an all Friesian herd being as economic as the Friesian/Jersey mix.

The basis for the mathematical appraisal focussed on maintaining an equilibrium between supply and demand. Legislation recently introduced by the European agriculture ministers has affected the demand side of the equation. The reaction of producers to the quotas which were introduced was to reduce yields by decreasing the level of concentrates in the diet and to cut back the numbers producing. In this instance, having diversity would have been of little use.

Overall the results from the analysis indicate that there can be potentially large benefits from having a stock of genetic material available for use by the commercial herd. Of the alternatives considered, and for the situations examined, it would appear to be better to concentrate resources primarily on establishing a stock of diverse genetic material. With low storage costs, a broad spectrum of material could be kept to cover for a wide range of possible future requirements. Maintaining a stock of specific breeds should be considered as being of secondary importance.

Further changes are likely in the dairy sector, and for the comparatively low cost of conserving a stock of genetic material, the benefits from its existence could be significant.

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APPENDIX A Calculating demand of liquid milk, butterfat and protein

For the purposes of the analysis carried out in this thesis, supply and demand need to be expressed as vectors of liquid milk, butterfat and protein yield. Calculation of the supply sector for each breed is comparatively straightforward and has already been covered in sufficient detail in Chapter 4. The subject for discussion here is the alternative methods used in the analysis for estimating levels of demand for the three products.

There are two alternative methods which have been used for estimating demand:

(i)estimate future milk demand (liquid and manufacture) from past data to which average composition levels for fat and protein are applied to derive an estimate of demand for the two products.

(ii)estimate demand for liquid consumption (for liquid, fat and protein) using the approach described in (i), and then calculate the requirements of the three products necessary for the manufacture of dairy products.

In both methods it is necessary to look at data relating to the demand for milk for liquid consumption and manufacture, the allocation of milk for manufacture between the assorted dairy products and the demand for the dairy products for the past decade or so. From the figures (Tables A-1, A-2 and A-3) several points of interest can be made. Firstly total sales of milk sold off farms in the UK has been increasing, caused primarily by an increase in the amount of milk going for manufacture. Milk for liquid sales has

Table A-1

Utilisation of milk sold off farms in the United Kingdom

April to March	Liquid sales	Manufacture (million litres)	Total
1959-60	7036	2640	9676
1964-65	7459	3251	10710
1968-69	7468	4189	11658
1969-70	7479	4384	11863
1970-71	7458	4644	12103
1971-72	7353	5181	12534
1972-73	7432	5944	13377
1973-74	7531	5783	13314
1974-75	7761	5407	13167
1975-76	7875	5513	13388
1976-77	7689	5957	13646
1977-78	7424	7230	14654
1978-79	7398	7765	15163
1979-80	7291	7869	15161
1980-81	7136	8076	15212
1981-82	7075	8087	15162

(Source MMB - Dairy Facts and Figures 1978-82)

Table A-2

Utilisation of milk for manufacture in the United Kingdom

(million litres)

April to March	Butter	Cheese	Condensed Milk	Whole Milk Powder	Fresh Cream	Sterilised Cream	Other Products	TOTAL
1968-69	1238	1241	630	214	664	97	105	4189
1969-70	1379	1276	607	207	706	100	109	4384
1970-71	1450	1428	617	196	742	99	112	4644
1971-72	1703	1671	594	236	766	97	114	5181
1972-73	2286	1837	578	209	829	83	122	5944
1973-74	1925	1932	596	243	873	91	123	5783
1974-75	1194	2263	564	238	941	74	133	5407
1975-76	1498	2228	503	195	919	69	101	5513
1976-77	2111	2041	553	178	893	74	107	5957
1977-78	3308	2093	575	184	914	62	93	7229
1978-79	3645	2256	557	202	958	60	86	7764
1979-80	3607	2377	526	213	987	65	95	7870
1980-81	3913	2335	476	245	952	52	103	8076
1981-82	3892	2445	451	254	906	35	104	8087

(Source: MMB Dairy Facts
and Figures 1978 and 1982)

Table A-3

U.K. Production and Domestic Disappearance of Milk Products

	Butter Prod (Thousand Tonnes)	Butter Dis	Cheese Prod (Thousand Tonnes)	Cheese Dis	Whole Milk Powder Prod (Thousand Tonnes)	Whole Milk Powder Dis	Fresh Cream Prod (mn Litres)	Fresh Cream Dis	Sterilised Cream Prod (Thousand Tonnes)	Sterilised Cream Dis	Condensed Milk Prod (Thousand Tonnes)	Condensed Milk Dis
1970	63.9	472.3	135.0	300.4	21.4	31.4	733.0	N.A.	16.8	N.A.	186.2	161.3
1971	65.8	232.3	162.3	314.9	27.4	33.5	760.8	N.A.	16.3	N.A.	178.6	157.0
1972	94.9	390.6	184.1	303.0	25.4	41.2	809.4	N.A.	13.9	N.A.	139.5	139.8
1973	96.8	424.9	182.0	324.3	22.2	30.1	869.1	916.7	14.6	N.A.	147.3	144.4
1974	53.5	490.1	217.7	331.5	26.7	28.3	924.5	960.4	13.5	18.2	139.2	133.1
1975	47.6	512.4	234.8	350.0	24.3	21.4	933.2	953.9	11.6	15.1	125.4	122.5
1976	89.3	444.2	203.9	340.7	21.7	16.1	894.7	909.2	11.4	14.5	128.1	109.1
1977	133.7	412.7	206.3	312.5	22.0	11.4	906.8	925.4	11.3	13.2	140.4	98.8
1978	163.3	402.5	215.9	324.2	26.0	6.8	959.4	974.7	9.5	11.8	143.0	101.8
1979	160.5	376.2	234.2	350.0	24.1	N.A.	978.3	998.6	10.9	12.2	128.6	101.2
1980	168.4	322.8	237.3	336.5	30.8	N.A.	966.6	982.9	10.2			
1981	172.0	N.A.	241.8	N.A.	29.6	N.A.	917.2	N.A.	5.8	N.A.	110.2	N.A.
Self Sufficency Rate	52.17		70.52		N.A.		98.34		85.71		144.78	

(SOURCE: Dairy Facts and Figures 1978 and 1982) been gradually declining since 1975-76. It can, however, be seen that total sales since 1978-79 seem to have reached a plateau.

The level of milk being utilised for butter, cheese and whole milk powder has been increasing with utilisation for the production of condensed milk and sterlised cream dropping (milk for fresh cream production since 1968-69 has increased overall, but has dropped slightly since 1979-80). Looking to the future it could be argued from Table A-3 that the only areas of production which could justify increases in milk utilisation are butter and cheese, with the UK being almost self sufficient in cream, and over producing condensed milk and whole milk powder.

Three profiles of demand will be used for each of the alternative methods for estimating demand to examine the current structure.

(a)total demand staying constant;
(b)total demand increasing (i.e. milk for manufacture increasing, milk for liquid remaining constant);
(c)total liquid demand decreasing (milk for manufacture constant, milk for liquid consumption falling).

The base year for calculations in the model is 1980 - for the purposes of estimating demand the starting point (i.e. t=0) will be 1980/81.

Demand profile

(i)(a) - Constant demand

Total demand 1980/81 : 15212mn litres

1 litre of milk = 1.02969kgs

average composition levels - fat 3.8%
protein 3.3%

Therefore assumed demand - for fat 595 thousand tonnes
protein 517 thousand tonnes

(i)(b) - Total demand increasing

Figures for the utilisation of milk for manufacture were regressed as a linear function of time, giving the following regression equation:

$$D_m = 7903.2 + 319.7 \times \text{Time} \quad (\text{Time} = 0 \text{ for } 1980/81)$$

$R^2 = 90.3\%$ T value 11.05

Using the same composition levels as above

	Milk	Fat	Protein
	mn litres	thousand tonnes	
T = 0	7903	309	268
1	8223	322	279
2	8543.6	334	290
3	8862.3	347	301
4	9182.0	359	312
5	9501.7	372	323
6	9821.4	384	334

Assuming that liquid demand is constant at the 1980/81 level of 7136mn litres of liquid, 279 thousand tonnes of fat and 242 thousand tonnes of protein. This gives us the following demand profile.

	Milk	Fat	Protein
	mn litres	thousand tonnes	
T = 0	15039	588	510
1	15359	601	521
2	15678.6	613	532
3	15998.3	626	543
4	16318	638	554
5	16637.7	651	565
6	16957.4	663	576

(i)(c) - Total liquid demand decreasing

The results from regressing milk for liquid consumption against time did not produce as favourable results as above, due to an increase in demand from 1972-3 until 1975-76, since which it has been declining. For the purposes of this particular evaluation, let us assume that liquid consumption is falling at the rate of 1.5% per annum, giving us the following pattern:

		Milk	Fat	Protein
		mn litres	thousand tonnes	
T =	0	7136	279	242
	1	6993	274	237
	2	6853	268	233
	3	6716	263	228
	4	6582	257	224
	5	6450	252	219
	6	6321	247	215

Assuming that the level of demand for milk for manufacture stays constant at the 1980/81 level - 8076 litres of milk, 316 thousand tonnes of fat and 274 thousand tonnes of protein, the total demand profile is:

		Milk	Fat	Protein
		mn litres	thousand tonnes	
T =	0	15212	595	516
	1	15069	590	511
	2	14929	584	507
	3	14792	579	502
	4	14658	573	498
	5	14526	568	493
	6	14397	563	489

The basis for the calculation of demand for these next three demand profiles is that liquid for manufacture is pooled centrally, and split into the component parts - liquid, fat and protein - that are required in the production of dairy products. Requirements for the production of dairy products has been estimated on the basis of milk allocated to the production of individual products and by making reference to the C.A.S. Report (1978) and Milk Marketing Board publications.

The assumption used in the following estimations are:

(i) that butter has an average fat content of 80% - the remaining 20% being liquid;

(ii)cream has an average fat content of 25% - the remaining 75% being liquid;

(iii)whole milk is required for the production of whole milk powder, condensed milk, cheese and the category referred to as "other products".

(ii)(a) - Demand constant

For this demand profile, liquid demand will be taken as the same as the (i)(b). The requirements for manufacture will be based on the level of milk allocated to the production of each dairy product in 1980/81.

	Allocation	Liquid	Fat	Protein
	mn ltrs		thousand tonnes	
Butter	3913	37.2	153	-
Cheese	2335	2335	91.4	79.3
Condensed Milk	476	476	18.6	16.2
Whole Milk Powder	246	246	9.6	8.4
Cream	1004	114.4	39.3	-
Other Products	103	103	4.0	3.5
TOTAL	8076	3311.6	315.9	107.4

This gives the following demand profile

liquid	10447.6	mn litres
fat	595	thousand tonnes
protein	349.4	thousand tonnes

(ii)(b) - Demand increasing

With regard to the comments made earlier, it will be assumed that the level of milk allocated to butter and cheese production will increase - allocation to the other diary products will remain constant.

Figures of the utilisation of milk for butter and cheese production were regressed as a linear function of time, giving the following results:

Butter = 3593.0 + 222.76 T (Time = 0 for 1980/81)

R^2 = 85.2% T value 6.30

Cheese = 2460.5 + 91.23 T

R^2 = 85.2% T value 8.72

		Allocation	Liquid	Fat	Protein
		mn litres	mn litres	thousand	tonnes
Butter	T = 0	3593.0	34.1	140.6	-
	1	3815.7	36.2	149.3	-
	2	4038.5	38.4	158.0	-
	3	4261.3	40.5	166.7	-
	4	4484.0	42.6	175.4	-
	5	4706.8	44.7	184.2	-
Cheese	T = 0	2460.5	2460.5	96.3	83.6
	1	2551.7	2551.7	99.8	86.7
	2	2642.9	2642.9	103.4	89.8
	3	2734.2	2734.2	106.9	92.9
	4	2825.4	2825.4	110.5	96.0
	5	2916.6	2916.6	114.1	99.1

This gives the following total demand profile

	Liquid	Fat	Protein
	mn litres	thousand	tonnes
T = 0	1057.0	587.4	353.7
1	10663.3	599.6	356.8
2	10756.7	611.9	359.9
3	10850.1	624.1	363.0
4	10943.4	636.4	366.1
5	11036.7	648.8	369.2

(ii)(c) - Demand decreasing

This is similar to (i)(c) in that milk for production remains constant but liquid consumption falls 1.5% p.a. using the following total demand profile:

	Liquid	Fat	Protein
	mn litres	thousand tonnes	
T = 0	10447.6	594.9	349.4
1	10304.6	589.9	344.4
2	10164.6	583.9	340.4
3	10027.6	578.9	335.4
4	9893.6	572.9	331.4
5	9761.6	567.9	326.4

Appendix B Calculating theoretical genetic improvement

The genetic improvement for traits expressed only be females is calculated using the formula below. It is not intended that this section should try to derive or prove formulae already widely accepted, but to demonstrate their usage in the context of this research.

The expected genetic change per year from selection.

$$= \Delta G = \frac{G_{BB} + G_{BC} + G_{CB} + G_{CC}}{L_{BB} + L_{BC} + L_{CB} + L_{CC}}$$

where $\Delta G_{BB} = i_{BB} \; r_{GI} \; \sigma_G$

and i = standardised selection differential (mean of selected average);

r_{GI} = accuracy of selection (correlation of additive genotypic value with index I used in selection);

σ_G = genetic standard deviation;

L = lag (in years)= generation interval (age of parents when their offspring are born);

BB = bulls to breed bulls;

BC = bulls to breed cows;

CB = cows to breed bulls;

CC = cows to breed cows.

When selecting bulls on their daughter's records (average of n daughters):

$$r_{GI} = \frac{1}{2} h \sqrt{\frac{n}{1 + (n-1) \frac{1}{4} h^2}}$$

where n = number of daughters;

h^2 = heritability;

h = the square root of the heritability = $\frac{\sigma_G}{\sigma_P}$

σp = standard deviation of the phenotype which is taken as 1

When selecting cows on m records per cow

$$r_{GI} = h \sqrt{\frac{m}{1 + (m-1) t}}$$

t = repeatability (correlation between the records of a cow)

The theoretical annual genetic improvement will be calculated using the following values (Maijala, (1974)).

	h^2	t	Coefficient of variation %
milk yield	0.25	0.35	14
fat yield	0.23	0.35	14
protein yield	0.30	0.35	13
fat %	0.47	0.60	8.1
protein %	0.44	0.60	5.2

The selection will be based on:

BB = 50 daughter records per bull
BC = 50 daughter records per bull
CB = 3 individual records per cow
CC = 2 individual records per cow

The values necessary for calculating the theoretical genetic improvement can be seen in Table B-1. Application of these values in the formula can be seen below. The selection intensity figure relates to the proportion selected from a population - i.e. for bulls to breed bulls the selection intensity is 1 in 20. The selection differential values are the selection intensity values expressed as values from a normal distribution function.

Table B.1 Figures for calculating theoretical genetic improvement

	Lag	Selection intensity (%)	i	r_{GI} milk yield	fat yield	protein yield	fat %	protein %
BB	6	0.05	2.063	0.877	0.867	0.896	0.993	0.927
BC	7	0.20	1.400	0.877	0.867	0.896	0.933	0.927
CB	5	0.02	2.421	0.664	0.636	0.728	0.801	0.774
CC	5	0.90	0.195	0.609	0.583	0.667	0.767	0.741

Selecting for milk yield

$$\Delta G = \frac{\sigma G\left[(2.063 \times 0.877)+(1.400 \times 0.877)+(2.421 \times 0.664)+(0.195 \times 0.609)\right]}{6 + 7 + 5 + 5}$$

$= 0.207\ \sigma_G$

$= 0.207\ h$

= 0.1035 standard deviation units/year

Taking a mean of 5417 litres, and a coefficient of variation of 14%;

$\sigma = \bar{X} \times CV$

$= 5147 \times .14$

= 758.4 litres

$\therefore \Delta$ G/year $\approx 0.104 \times 758$

= 78.8 litres/year

= 1.47% of the mean/year.

Selecting for milk yield, therefore, the theoretical maximum improvement that could be expected is just under 79 litres per year. In achieving this, there will also be changes to the level of output of the other characteristics - unless efforts are made to prevent correlated responses.

The formula for calculating correlated responses is shown below.

$$\text{Correlated response} = R_1\ b_{G_{21}}$$

$$= R_1 \left[\frac{\text{Cov } G_2 G_1}{\sigma_{G_1}\ \sigma_{G_2}}\right] \cdot \frac{\sigma_{G_2}}{\sigma_{G_1}}$$

The correlated response is expressed in standard deviation units of trait 2, where R_1 is response of the main trait expressed in standard deviation units per year,.

$$\sigma_{G2} = h_2$$

$$\sigma_{G1} = h_1$$

$$\frac{\text{Cov } G_2 G_1}{\sigma_{G_1} \; \sigma_{G_2}} = {}^{r}G_{21}$$ where ${}^{r}G_{21}$ is the genetic correlation between traits 2 and 1

The correlated response on fat yield when selecting for milk yield, using the genetic correlation from Table B-2, can be seen below

$$R_1 \left[{}^{r}G_{21} \right] \frac{h_2}{h_1} = 0.104 \times 0.813 \times \frac{0.479}{0.500}$$

$$= 0.081\,\sigma\ /\text{year}$$

Taking the mean fat yield as being 211 kgs and a coefficient of variation of 14%, the correlated response, when selecting for milk yield, is about 2.4 kgs of fat per year, or 1.1% of the mean fat yield.

Table B.2 Genetic correlation values

	milk yield	fat yield	protein yield	fat %	protein %
Milk yield		0.813	0.845	-0.312	0.280
Fat yield			0.849	0.206	0.138
Protein yield				0.081	0.227
Fat %					0.582

Appendix C Details of the linear programming model

The basic premise of the model is:

$$TS \geqslant TD$$

where TS = a vector of total supply

TD = a vector of total demand

For the purposes of this evaluation:

$$TD = \begin{bmatrix} TDM \\ TDF \\ TDP \end{bmatrix}$$

$$TDM = \sum_{b} (LM (B,T) \times N (B,T)) \pm \gamma_1$$

$$TDF = \sum_{b} (SF (B,T) \times N (B,T)) \pm \gamma_2$$

$$TDP = \sum_{b} (SP (B,T) \times N (B,T)) \pm \gamma_3$$

TDM = total demand for milk in any period;
TDF = total demand for fat;
TDP = total demand for protein;

and

LM (B,T) = supply of liquid milk from breed B in period T;
SF (B,T) = supply of fat;
SP (B,T) = supply of protein;
N (B,T) = number of adult females of breed B producing in period T

γ_1, γ_2 and γ_3 are the balances between supply and demand. For each breed:

$$N (B,T) = N (B,T-1) + I (B,T) - W (B,T) - AW (B,T)$$

$$I (B,T) = 0.5 \alpha_1 (F(B,T-3) + F (B,T-2)) - M (B,T)$$

$$W (B,T) = \alpha_2 N (B,T-1)$$

$$AW (B,T) \leq \alpha_3 I (B,T)$$

$$F (B,T) = 0.5 \alpha_4 (0.25 N (B,T) + 0.75 N (B,T-1)) - BX (B,T)$$

Where I = introduction to the adult female herd;
W = involuntary withdrawals;
AW = additional withdrawals;
F = female calf births;
M = heifers sold from the dairy herd;
BX = calves born as a result of a cross with a beef bull.

α_1, α_2, α_3 and α_4 are constants. α_1 represents the percentage that survive from birth to adult; α_4 is the calving survival rate. α_2 is the proportion of involuntary removals and α_3 is the limit on the level of additional withdrawals.

The activity level of each variable was determined by the objective function, which was to minimise:

$$\sum_T \Big[\sum_B \{ (C1\ (B,T) \times N\ (B,T)) + (C2\ (B,T) \times I\ (B,T)) - (C3\ (B,T) \times AW\ (B,T)) - (C4(B,T) \times BX\ (B,T)) - (C5\ (B,T) \times M\ (B,T)) \} + (C6\ (T) \times (TSM - TDM)) + (C7\ (T) \times (TSF - TDF)) + (C8\ (T) \times (TSP - TDP)) \Big]$$

Where C1 (B,T) = costs of milk production;
C2 (B,T) = cost of introductions;
C3 (B,T) = income from the sale of additional culls;
C4 (B,T) = income from the sale of beef cross calves;
C5 (B,T) = income from the sale of heifers to the beef herd;
C6 (T) = cost of an imbalance in the supply and demand of milk
C7 (T) = cost of an imbalance in fat;
C8 (T) = cost of an imbalance in protein;

TSM = total supply of milk
TSF = total supply of fat;
TSP = total supply of protein.

The model was run for a period of 5 years using the Multi Purpose Optimisation System (MPOS) packages at the University of Manchester Computer Centre (UMRCC). Due to the size of the model, it was more efficient to create a matrix of the non-zero values, which was then called by the control program. The data file was created by a Fortran IV program, a copy of which can be seen below. This fortran program was run on the VAX 11/780 at the University of Stirling.

An example of a two breed model, in matrix format, covering 3 periods can be seen on the inside of the rear cover.

```
C       The purpose of this program is to construct a matrix of values
C       to be used in a Linear Programming model of the U.K. dairy herd.
C
        REAL DEM(5,3),Z(20,4),X(116,171),LM(4,5),SF(4,5),SP(4,5),TDM,
     C  TDF,TDP,C1(4,5),C5(4,5),C6(4,5),C7(4,5),
     C  C8(4,5),VAL(4,4),ZZ(3,2),DISC
C
        INTEGER T,I,J,KI,L,IJ,KJ,U,V,W,Y,XZ,XV,XW,XU,R1,R2,R3,JI,JK
C
C       Having identified REAL and INTEGER values, it is now necessary
C       to read into the program certain values.  DEM.DAT is a data file
C       containing projected levels of demand for liquid, fat and protein
C       Z.DAT contains values such as moratlity percentage and the 'm'
C       and 'c' values for calculating yields. VAL.DAT is the data file
C       containing starting values i.e N(B,T-1),F(B,T-1),F(B,T-2) and
C       F(B,T-3) for all breeds.  ZZ.DAT contains values for calculating
C       the costs of over and under production.
C
C
        READ(9,*)((DEM(I,J),J=1,3),I=1,5)
        READ(8,*)((Z(KI,L),L=1,4),KI=1,20)
        READ(7,*)((VAL(IJ,KJ),KJ=1,4),IJ=1,4)
        READ(11,*)((ZZ(JI,JK),JK=1,2),JI=1,3)
C
C
C       T states the starting value in terms of time period, TM is
C       the number of periods for which the model will run, and BD is
C       the number of breeds in the model.
C
        T=0
        TM=5
        BD=4
        DISC=0.05
C
C
C       Start of the first loop; the number of repetitions being
C       dependent upon the number of time periods of interest.
C
  25    BR=0
        T=T+1
        TDM=DEM(T,1)*1000.0
        TDF=DEM(T,2)
        TDP=DEM(T,3)
C
C       Start of the second loop, within which values for the different
C       breeds are calculated.
C
  15    BR=BR+1
C
C       LM(BR,T)= liquid milk yield (litres) of breed BR in time T
C       SF(BR,T)= butterfat yield (kgs) of bread BR in time T
C       SP(BR,T)= protein yield (kgs) of breed BR in time T
C
        LM(BR,T)=Z(5,BR)+Z(6,BR)*T
        SF(BR,T)=Z(7,BR)+Z(8,BR)*LM(BR,T)
        SP(BR,T)=Z(9,BR)+Z(10,BR)*LM(BR,T)
C
C       Cost calculations : C1 - costs of production
C                           C5 - cost of introductions
C                           C6 - income from sale of culls
C                           C7 - income from sale of crossed beef calves
C                           C8 - income from sale of heifers leaving dairy
C                                herd
```

```
C
      C1(BR,T)=(Z(11,BR)+Z(12,BR)*T)/(1.0+DISC)**(T-1)
C
      C5(BR,T)=(Z(13,BR)+Z(14,BR)*T)/(1.0+DISC)**(T-1)
      C6(BR,T)=(Z(15,BR)+Z(16,BR)*T)/(1.0+DISC)**(T-1)
      C7(BR,T)=(Z(17,BR)+Z(18,BR)*T)/(1.0+DISC)**(T-1)
      C8(BR,T)=(Z(19,BR)+Z(20,BR)*T)/(1.0+DISC)**(T-1)
C
C
      R1=(5*BD)+3
      R2=(7*BD)+6
      R3=(BR-1)*7
      U=(R1*(T-1))+((BR-1)*5)
      V=(R2*(T-1))+R3
      W=(R2*(T-2))+R3
      Y=(R2*(T-3))+R3
      XZ=(R2*(T-4))+R3
      XY=(5*BD)+(R1*(T-1))
      XV=(7*BD)+(R2*(T-1))
      XW=R1*TM
      XU=(R2*TM)+1
C
C
C
      X(1+U,1+V)=1.0
      X(1+U,2+V)=-1.0
      X(1+U,3+V)=1.0
      X(1+U,4+V)=1.0
C
      X(2+U,3+V)=1.0
C
C
      X(3+U,2+V)=1.0
      X(3+U,6+V)=1.0
C
      X(4+U,6+V)=1.0
      X(4+U,2+V)=-Z(2,BR)
C
      X(5+U,1+V)=-0.125*Z(4,BR)
      X(5+U,5+V)=1.0
      X(5+U,7+V)=1.0
C
      X(1+XY,1+V)=LM(BR,T)
      X(2+XY,1+V)=SF(BR,T)/1000.0
      X(3+XY,1+V)=SP(BR,T)/1000.0
C
C     Lines 11200 -11600   specifying values of the objective function
C     relating to specific breeds in particular time periods.
C
      X(1+XW,1+V)=C1(BR,T)
      X(1+XW,2+V)=C5(BR,T)
      X(1+XW,4+V)=-C6(BR,T)
      X(1+XW,7+V)=-C7(BR,T)
      X(1+XW,6+V)=-C8(BR,T)
C
      IF(T.EQ.1)GO TO 100
C
      X(1+U,1+W)=-1.0
      X(2+U,1+W)=-Z(1,BR)
      X(5+U,1+W)=-0.375*Z(4,BR)
C
      IF(T.EQ.2)GO TO 200
C
```

Glossary of Terms

Backcross — Where a crossbred offspring (the progeny from crossing two different breeds) is bred back to one of the parent's breeds (which are usually purebred).

Conformation — the term refers to the shape of the animal.

Generation interval — the average age of the parents when the offspring are born.

Genotype — the genetic make-up of the animal.

Germ plasm — the reproductive cells - male sperm and female egg - that unite to produce the offspring.

Heritability — the strength of inheritance of a trait, usually denoted by h^2.

Hybrid vigour — where the offspring is better than the mean of its parents.

Inbreeding — mating of animals that are more closely related to each other than the average of the population, i.e. animals which share one or more ancestors.

Phenotype — the outward expression of an animal's genetic make-up (the genotype) - i.e. its physical form, its colour or its behaviour.

Selection intensity — the proportion selected from a population.

Selection plateau — the level reached after a period of selection when no further progress is apparent.

T= -3 Breed 1: N I W AW F M BX
-.5a

Breed 2: N I W AW F M BX
-.5a

T= -2 Breed 1: N I W AW F M BX
-.5a
-.5a

Breed 2: N I W AW F M BX
-.5a
-.5a

T= -1 Breed 1: N I W AW F M BX
-1
-b
-.375d
-.5a
-.5a

Breed 2: N I W AW F M BX
-1
-b
-.375d
-.5a
-.5a

OBJECTIVE FUNCTION MINIMISE

T= 1 Breed 1: N I W AW F M BX
1 -1 1 1 1
1 1
-c 1
-.125d 1 1
-1
-b
-.375d
-.5a
LM
SF
SP
C1 C2 -C3 -C5 -C4

Breed 2: N I W AW F M BX
1 -1 1 1 1
1 1
-c 1
-.125d 1 1
-1
-b
-.375d
-.5a
LM
SF
SP
C1 C2 -C3 -C5 -C4

T= 2 Breed 1: N I W AW F M BX
1 -1 1 1 1
1 1
-c 1
-.125d 1 1
-1
-b
-.375d
LM
SF
SP
C1 C2 -C3 -C5 -C4

Breed 2: N I W AW F M BX
1 -1 1 1 1
1 1
-c 1
-.125d 1 1
-1
-b
-.375d
LM
SF
SP
C1 C2 -C3 -C5 -C4

T= 3 Breed 1: N I W AW F M BX
1 -1 1 1 1
1 1
-c 1
-.125d 1 1
LM
SF
SP
C1 C2 -C3 -C5 -C4

Breed 2: N I W AW F M BX
1 -1 1 1 1
1 1
-c 1
-.125d 1 1
LM
SF
SP
C1 C2 -C3 -C5 -C4

SLACK VARIABLES: S1 S2 S3
1 (S1), 1 (S2), 1 (S3) — rows TDM(1), TDF(1), TDP(1)
1 (S1), 1 (S2), 1 (S3) — rows TDM(2), TDF(2), TDP(2)
1 (S1), 1 (S2), 1 (S3) — rows TDM(3), TDF(3), TDP(3)
C6 C7 C8

R.H.S.
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
TDM(1) TDF(1) TDP(1)
TDM(2) TDF(2) TDP(2)
TDM(3) TDF(3) TDP(3)

N	Number of adult females
I	Introductions to the herd
W	Withdrawals (deaths,etc.)
AW	Additional Withdrawals
F	Female births
M	Number sold prior to entering adult herd
BX	Beef crosses
a	Proportion of female calves surviving from birth to entering adult herd.
b	Proportion of adult herd culled during year.
c	Maximum level of additional withdrawals.
d	Proportion of calves born (= 1 - mortality rate).

LM	Liquid milk yield (litres)
SF	Fat yield (kgs)
SP	Protein yield (kgs)
TDM	Total demand for liquid milk
TDF	Total demand for fat
TDP	Total demand for protein
C1	Cost of production
C2	Cost of introductions
C3	Income from sale of cows
C4	Income from sale of Beef crossed calves
C5	Income from sale of heifers
C6, C7 & C8	Costs of a supply imbalance
S1, S2 & S3	Imbalances between supply and demand