AN ECONOMIC APPRAISAL OF PIG IMPROVEMENT

IN GREAT BRITAIN

Thesis submitted for the degree of

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by

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Abstract

This thesis reports a cost-benefit appraisal of pig improvement work in Great Britain in recent years. Estimates of the genetic improvement achieved by the Meat and Livestock Commission's Pig Improvement Scheme and by certain independent breeding companies are taken and the impact of this improvement on the commercial industry as a whole is estimated and valued. This value is then compared with estimates of the scale of investment in pig improvement. The results show returns have been very high compared with costs and compare well with the high returns reported in other areas of agricultural research and development (an internal rate of return of 70% is calculated). A detailed sensitivity analysis is carried out which shows the overall results to be quite robust, although a number of areas where more accurate information would be valuable are highlighted. A number of wider issues relating to animal breeding in general are discussed. In particular the discount rate is considered in some detail and the effects on net present value of a wide range of rates (as quoted in the animal breeding literature) are demonstrated. A number of areas for possible future consideration are mentioned.

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TECHNOLOGICAL ECONOMICS RESEARCH UNIT

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- Animal breeding
- Fisheries

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Contents

Chapter 1

INTRODUCTION

1.1 AIM OF THIS THESIS

The aim of this thesis is to evaluate investment in the genetic improvement of pigs in recent years in Great Britain. Such an evaluation may be useful in that:

1. It will provide a check on the value of this past investment. Also by questioning the worth of past investment and attempting to accurately estimate its value, consideration is encouraged of a number of issues relating to pig improvement on which some discussion may be valuable. Some areas of doubt may be highlighted and areas for further consideration and research suggested.

2. The study will allow conclusions to be drawn and comments made with regard to future investment in pig improvement.

3. A number of issues will be dealt with of interest in relation to the appraisal of animal improvement work in general. A possible approach will be illustrated and the possible significance of certain factors will be shown.

1.2 SUBJECT AREA

Some comments on the general approach and on the boundaries of concern are appropriate at this point.

1. Viewpoint

The study is in the form of a "Social cost benefit analysis". That is, appraisal of costs and benefits is from the point of view of society as a whole, not any group or body within it. Private and public investments are included; whatever the aims of the investors the value of their investments to society as a whole may still be appraised. The possible effects of the investment in terms of redistributing value between individuals or groups is ignored; concern is with the net gain or loss to society. Ignoring such distribution effects is a practice not without possible criticism. The issue is discussed in several general texts (eg Layard, 1972). A strict criterion for welfare improvement would be that a project is supported if someone gains but nobody loses. If some gain while others lose the picture is less clear cut. A commonly accepted criterion is that a project is supported if those who gain are in a position to compensate those who lose, even if this does not actually happen (the Hicks - Kaldor criterion). Such a criterion is adopted in this study. The figures available and approach adopted mean that the question of the distribution of benefits cannot be dealt with with any great precision though some comments will be made.

2. Retrospective Study

It may be noted that cost-benefit analysis is normally considered as a planning tool. The current study is not unusual in dealing with past investment, however, and a number of such studies are documented in the agricultural economics literature (see

Chapter 2). The aims of these past studies are very much the same as those outlined above for this study. One possible criticism of such works that is perhaps unavoidable, is that the subjects selected for appraisal tend to be selected as proven successes. This need not deny the value of such studies but means that care must be taken with regards what conclusions may be drawn from them.

Essentially investment since 1966 is considered, that being the year in which the combined central testing scheme, which it may be argued was the first truly effective scheme for pig improvement, was established (a brief description of the scheme and its background, and of the other sources of improvement considered in this study, is given in Chapter 3). Investments up to 1977 are considered (the last year for which figures for sales of improved stock are available from the MLC, see Chapter 5), though the effects of that investment in later years are considered. The year 1977 is taken as a base year for discounting calculations.

Further, more detailed definition and explanation of the boundaries of the study will be given at points through the subsequent chapters.

1.3 FORMAT

Chapter 2, "Cost Benefit Analysis in Relation to Animal Breeding and Agricultural Research" is a consideration of some areas of relevant literature. Three areas are considered:

1. Investment appraisal criteria, with particular reference to the discount rate.

2. Investment appraisal in animal breeding.

3. Investment appraisal in agricultural research in general.

The discount rate is singled out as this has been an area of particular interest to animal breeders recently (eg Smith, 1978). Appraisals in the animal breeding literature are considered with particular note taken of their treatment of discount rates and risk. The field is widened to include other areas of agricultural research both in search of guidance on general approach, and to examine the scales of benefits reported and subject areas dealt with.

Chapter 3 presents a description of relevant aspects of the pig industry in Great Britain in recent years which, with Chapter 2, provides essential background to the study as a whole.

The estimation of benefits begins in Chapter 4 with a consideration of the genetic progress achieved in the herds achieving progress and is continued in Chapters 5 and 6 in which the effects of the genetic change on the national herd are estimated and valued. Costs are estimated separately in Chapter 7 before being compared with benefits in the synthesis in Chapter 8. Also in Chapter 8 the sensitivity of the results estimated is tested with respect to a number of factors, both genetic and economic. In considering the discount rate, already mentioned, a wide range of rates is used to illustrate how the scale of estimated net benefits may vary with the sort of rates that have been suggested in some animal breeding papers.

In Chapter 9 some wider issues first raised earlier in the thesis and certain possible future developments are discussed before concluding remarks are given in Chapter 10.

Chapter 2

COST BENEFIT ANALYSIS IN RELATION TO ANIMAL BREEDING AND AGRICULTURAL RESEARCH

The aim of this chapter is to consider certain areas of literature which may be relevant to the main study in that:

1. They may give guidance in terms of general approach.

2. They put the current study into context with other work that has been done.

It has already been stated that the study aims to consider the costs and benefits of pig improvement in Great Britain from the point of view of society as a whole. Social cost-benefit analysis is a well developed field with an extensive literature. It is not considered within the scope of this chapter to attempt to discuss all of this literature. It may be noted that a number of general reviews have been produced (Prest and Turvey, 1965; Layard, 1972; Dasgupta and Pearce, 1972). One aspect of the cost benefit analysis literature, investment appraisal criteria (including the discount rate), is singled out for some consideration. This is of particular interest and relevance to the animal breeding field (Smith, 1978) and is the subject of Section 2.1. Section 2.2 is a brief review of some papers concerning investment appraisals from the animal breeding literature, with particular emphasis on the issues raised in Section 2.1. The final section of the chapter (Section 2.3) extends the scope of the review to looking at appraisals in agricultural research in general.

2.1 APPRAISAL CRITERIA FOR INVESTMENTS IN THE PUBLIC SECTOR

The major part of this section is a consideration of the appropriate discount rate for use in the public sector. First, however, an attempt is made to outline the objectives of investment appraisal criteria and some of the appraisal techniques available, including non-discounting techniques.

2.1.1 Purpose

Three possible aims of investment appraisal criteria may be determined:

1. To decide whether a particular project is, or was, worth doing. The present study is one of this nature.
2. To decide which of a number of alternative projects should be undertaken to maximise the benefit to society, perhaps subject to some budgetary constraint and possibly including mutually exclusive projects.
3. To achieve an optimal allocation of resources between the public and private sectors.

2.1.2 Appraisal Techniques

Firstly it is worth noting that non-discounting appraisal criteria do exist and are used in some instances in the private sector. Mishan (1975) reviews the most common of these appraisal techniques:

1. The cut-off period:

   A project is judged worthwhile if the initial investment is recouped within a set period.

2. The pay-back period:

   Projects are valued according to the length of time taken for the investment to be recouped.

3. The average rate of return:

   The average return for all the years of a project is expressed as a percentage of the initial outlay.

With the use of simple numerical examples Mishan discusses some of the shortcomings of each method. His final criticism, and the justification for discounting techniques, is that such criteria take no account of the pattern or profile of benefits (and costs) through time. From the businessman's point of view, earlier benefits offer the chance of further benefits through reinvestment. Even in the public sector, where a government body may not itself receive the benefits of investment in a reinvestable form, it is reasonable to suppose that society as a whole prefers earlier benefits to later benefits if the later benefits are no greater (see the discussion of discount rates below).

The main discounting techniques are:

(1) <u>Net Present Value</u> (NPV)

The value of the cash stream is determined to some point-in-time with reference to a given rate of interest. Most commonly that point-in-time is taken as the present.

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The criterion is then that the project is worth doing if:

$$NPV > 0 \qquad (1)$$

where

$$NPV = \sum_{t=0}^{t=n} \frac{B_t}{(1+r)^t} \qquad (2)$$

where B_t = net benefit (or cost) in year t

r = the discount rate expressed as a decimal rather than a percentage

and n = the number of years the appraisal is made over.

(2) Internal Rates of Return (IRR)

The discount rate is calculated which would bring the total value of the cost benefit stream to zero at a specific point in time. That is, the IRR is calculated by the equation:

$$\sum_{t=0}^{t=n} \frac{B_t}{(1+\lambda)} t = 0 \qquad (3)$$

where λ = the IRR

If λ is greater than some minimum acceptable figure the project is judged worthwhile.

Clearly comparison of IRRs or NPVs may be used to rank alternative projects.

The relative merits of the two approaches are discussed by several authors. The consensus, Dasgupta and Pearce (1972) conclude, is in favour of the NPV rule, at least for appraisals in the public sector. They list the most commonly quoted reasons, the most acceptable of which are probably:

1. IRRs will give a disproportionately high weighting to early benefits compared with later benefits and will tend to favour projects bunching their benefits into the early part of their economic lives relative to other projects.

2. The solution to equation (3) may not lead to a unique solution. Indeed for every change of sign in the stream of net benefits there will be a solution.

Other arguments given include ease of calculation and allowing comparison to be made in circumstances where different discount rates are applicable at different points in time.

A thorough theoretical comparison of the two approaches is given by Hirschliefer (1958) using indifference curve analysis. He illustrates how certain possible ambiguities and misleading results can occur with the two criteria and concludes in favour of the NPV method.

These arguments are perhaps most significant when ranking alternative projects. In looking at one project in isolation the IRR may be an adequate criterion. In the present study NPV will be taken as the criterion for evaluation. An IRR will be calculated, however, to allow some comparison with published IRRs from other studies (see Section 2.3).

2.1.3 Discount Rates

In terms of the appropriate discount rate for public sector investment appraisals, two schools of thought may be determined:

1. Social Time Preference.
2. Social Opportunity Cost.

The difference arises from the alternative aims of appraisal criteria mentioned above. Each is considered in turn and a theoretical synthesis of the two approaches is described. After that the treatment of risk is considered and some general conclusions are drawn. Before considering the social time preference approach, however, two points can be made over which there seems fairly general agreement:

(a) Constant Rates

There is no a priori reason why the discount rate should be constant for all years. That is, there is no reason why the rate at which 1971 values are discounted to make them equivalent to 1970 ones should be the same as the rate needed to compare 1981 and 1980 values (as pointed out by Feldstein, 1964). However, in cost-benefit analyses the assumption is almost invariably made that the rate is constant, and this will be assumed in the current analysis also.

(b) Inflation

In times of inflation market rates of interest will be increased to allow for the expected rate of change in prices. Since concern here is with the subjective rate of substitution between real consumption in one period and another, a real rate of interest is required for discounting. If the money rate is "i", the

the inflation rate "p" and the real rate "r", then:

$$(1+r) = \frac{(1+i)}{(1+p)} \quad (4)$$

or

$$r = \frac{1-p}{1+p} \quad (5)$$

A common simplifying assumption in cost-benefit analyses is that inflation affects both costs and benefits equally and calculations are carried out in constant prices with a real rate of interest. Such an assumption is made below. Smith (1978) has introduced the question of adjusting monetary rates of interest for inflation to the animal breeding literature.

1. Social Time Preference

The Social Time Preference (STP) approach is concerned with the role of the discount rate in comparing consumption choices at different points in time. Simple observation confirms that individuals have a preference for benefits now rather than in the future, if the benefits are of the same scale. Possible reasons for this preference might be:

- As people grow richer with time then one unit of consumption will be worth proportionately less. This argument may be extended for society as a whole (Tullock, 1964).
- There is uncertainty attached to postponing consumption.
- Time cannot be reversed. Future consumption can always be substituted for present consumption by holding stocks but the reverse is not possible except through the services of a lender, which is not cost free.

The concern of economists of the STP school has been with the extent to which such a preference can be measured for society as a whole and whether it will lead to an optimal allocation of resources through time from society's point of view. Layard (1972) argues that in a perfect world the market rate of interest on risk-free, long-term bonds could be taken as an indicator of STP but in practice many market imperfections and distortions exist which make this an inadequate indicator. Even if society's time preference can be measured, a number of arguments have been put forward why discount rates based on observed time preference are too high. These include:

(a) Myopia:

Interest rates reflect individuals' ex-ante anticipation of the relative value of future consumption. It has been argued that individuals under-estimate the pleasure future consumption will give them; they are the victims of "defective telescopic faculty". Their rate of time preference tends to be too high and they tend to save and invest less than if they were perfectly rational beings.

(b) Isolation Paradox:

This argument was put forward by Sen (1961), extended by Marglin (1963), criticised by Lind (1964) before being reformulated by Sen (1967). It relates to the pleasure derived by individuals in one generation from contemplating the welfare of others and their heirs. In the free market these external effects are ignored and individuals maximise their own utility taking the savings decisions of others as exogenous to their own decisions, it is argued. This leads to a greater preference for current consumption than would be seen if individuals could bargain or take a collective decision via the political process.

(c) Future generations:

It has been argued that by discounting future consumption the welfare of future generations is being ignored and projects are judged solely in terms of their effects on the welfare of the current generation.

(d) Irreversibilities:

Related to the question of future generations is the issue of "irreversibilities" mentioned by several writers (Baumol, 1968; Layard, 1972; Price, 1973; etc). If the soil is poisoned so that is can never be used again, or in animal breeding programmes selection is so intensive it leads to loss of genetic variation, then assets are being used which cannot be replaced. All the resources of future generations cannot restore them. Price argues for very low rates, though Baumol argues that selective subsidies would be more appropriate, in this case, than "tampering" with the discount rate.

Clearly then, the decision as to the correct STP rate for use in investment appraisals is not a straightforward one. In practice choosing a rate is very much a value judgement. At one extreme an "authoritarian" might argue that the reasons for time preference are irrational and should be ignored, so that the rate should be set as low as possible. The "democrat" on the other hand, accepting irrationality and its effects as natural, might prefer to set the rate rather higher. A rate of 3% here might be a reasonable compromise.

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An alternative to attempting to identify time preference not considered so far is to try and derive an optimal rate from first principles. Attempts have been made to do this, and one approach, based on optimal growth theory, has been described by several writers (Layard, 1972; Dasgupta and Pearce, 1972; Pearce, 1971). The method is based on the assumption of a diminishing marginal utility of consumption. In its simplest form it is illustrated that two parameters are required to estimate the discount rate: the elasticity of the marginal utility function, and the required rate of growth of consumption. While the former can be measured, however, the latter again depends on a value judgement being made.

2. Social Opportunity Cost

The Social Opportunity Cost (SOC) approach is concerned more with the allocation of resources between the public and private sectors. Given the overall level of employment in the economy, the decision to devote resources to public investment means that resources will then become unavailable for use by the private sector. Baumol (1968) then argues that the appropriate rate of discount is one which reflects the opportunity cost for society. The transfer of resources should only take place when a potential public project offers social benefits greater than the loss sustained by removing those resources from the private sector, and the discount rate should be chosen in such a way as to ensure that.

Baumol analyses the processes by which market imperfections, taxes and risk raise interest rates in the private sector. He then argues that it is irrelevant that market rates in the private sector are high because of "distortions". These rates are the rates used by the private sector to allocate resources and therefore the marginal yield in the private sector will be determined by them. Baumol concludes "that society cannot come out ahead by taking resources that have been bringing in annual benefits amounting to 16% of the resource values and transferring them to uses where they will yield only 5%".

3. A Synthesis of the Two Approaches

In his paper, Baumol considers the possible division of funds between those drawn from current consumption and those drawn from investment. He argues that the opportunity cost for funds drawn out of consumption will be the same as those from investment. Feldstein (1972), however, argues that this view is based on an ambiguity in the notion of opportunity cost. Baumol's argument is based on the principle that consumption funds could be invested in the private sector to yield a return higher than the social time preference rate. Feldstein sees the actual opportunity cost of any resources is their value in the alternative use they would have been put to. While the two would coincide in a perfectly functioning economy, with the imperfections present in the investment market they will not. Pearce (1971) points out that consumption sacrificing methods of financing a project produces a greater shift of resources to future generations than the use of investment sacrificing methods. The more common view is that the appropriate discount rate for projects financed wholly out of funds drawn from consumption would be the STP rate (Mishan, 1971; Marglin, 1963; Feldstein, 1972).

Mishan shows that if the Government allows public bodies to invest in any projects (including private sector ones), then the appropriate rate for all funds is the market rate. Given the political constraints on public funds, however, this case can be seen to be unrealistic.

It therefore appears that both the STP and the SOC rates can be relevant to the same project. The simplest method of reconciling the two is the use of a weighted average. If, for a particular project, a proportion Q of the funds is drawn from investment, and (1-Q) from consumption, then the appropriate discount rate is "i" where:

$$i = \frac{r}{(1-Q)} + \frac{P}{Q} \qquad (6)$$

where r = STP

p = SOC

Feldstein (1972) illustrates cases where this approach would lead to erroneous results, however. He argues in favour of using a "shadow price" for investment funds forgone and discounting at the STP rate. This means the opportunity cost of investment funds is allowed for by charging them to a project at a price reflecting the present value of their worth to the private sector. For £1 diverted from private sector consumption, the present value is £1. For £1 diverted from private investment, the present value is the expected returns to infinity of the investment, discounted at the STP rate.

It can be shown that if the private sector rate of return is p and the STP rate is r, the present value of £1 diverted from private investment is £(p/r) (Layard, 1972). Thus if Q is the proportion of funds diverted from private investment (as above) £1 of investment in a particular project has a shadow price of:

$$£(p/rQ + (1-Q))$$

This argument was first proposed by Marglin (1963) and perhaps represents the most acceptable current view on discount rates from the theoretical point of view. It can be seen as reconciling the two issues involved: comparing consumption at different points in time and achieving an optimal allocation of resources between the public and private sectors. Morawitz (1972) in supporting the method points out these two aims and argues that with only one policy tool (the discount rate) it would be only chance if both targets were reached. With effectively a second tool in shadow pricing, progress can be made towards two goals simultaneously.

The use of the technique, however, is limited by knowledge of Q. At one extreme (Q=0) the procedure reduces to simple use of the STP rate. At the other extreme (Q=1) the method reduces approximately to the SOC rate. There is no real guidance on what value Q actually has.

4. Risk

All cost and benefit estimates are subject to some degree of uncertainty. Commonly in investment appraisals uncertainty is allowed for by increasing the discount rate for risky projects. Two questions must be asked regarding the validity of doing this in public sector appraisals, however:

- Is it appropriate to adjust for uncertainty?
- Is this the correct way to adjust for uncertainty?

a. The need to adjust for uncertainty

Arrow and Lind (1970) show that no allowance for uncertainty is necessary where the costs and benefits of a project are spread over a large population (the effects of loss for any individual being very small). This is true where benefits and costs are depletable in that one extra person's participation in the financing of a project reduces the share held by others. Where benefits and costs are undepletable, Fisher (1973) has shown that uncertainty attaching to outcomes cannot be ignored. Thus it is important on whom the costs and benefits fall. In terms of animal breeding projects, the costs involved are the real resources used in achieving progress and are obviously depletable. The benefits however, may be seen as undepletable: a general improvement in an animal population from which any one producer or consumer can receive the benefits without reducing the benefits to others. Thus risk may be seen as a significant factor in animal breeding projects, at least in terms of benefits.

b. Method of dealing with uncertainty

Loading the discount rate for risk implies that uncertainty is a geometric function of time. This is perhaps a more reasonable implication for the majority of appraisals than the other commonly used method of adjusting for risk, truncating the stream of benefits at some arbitrary point. The corresponding implication of this latter alternative would be that there is no uncertainty up to a certain point and infinite uncertainty thereafter. In practice, however, both methods must be fairly arbitrary (see Chapter 8).

5. Conclusions on the Discount Rate

In conclusion two schools of thought may be identified in the cost-benefit analysis literature which have been reconciled satisfactorily with one another in theory, though perhaps less satisfactorily in practice. Reconciliation of course is only necessary if the social time preference rate and social opportunity cost rate are different. It has recently been shown that the private sector rate of return has been so low that the problem effectively disappears (HMSO, 1978). Measuring the real rate of return on capital earned by British industry in recent years a rate of 5% was found. This is much closer to the 3% social time preference rate suggested above. If risk is added too, the 5% suggested in HMSO (1978) may even appear too low. In the main study a 5% rate is taken as a base for calculations, with higher rates included to test sensitivity.

2.2 INVESTMENT APPRAISAL IN ANIMAL BREEDING

The purpose of this section is to consider papers in the animal breeding literature concerned with investment appraisals and appraisal criteria. Other animal breeding papers will be quoted only as they are relevant later in the thesis. The conclusion is drawn above that non-discounting criteria are inadequate for projects where costs and benefits occur over several years as in animal breeding. It appears that there is now a widespread acceptance of this in the animal breeding field so concern is further limited to papers using discounting techniques.

The use of discounting techniques was first seen in the animal breeding literature in Poutous and Vissac (1962). They traced the implications of one round of artificial insemination in cattle through subsequent generations and considered the effects on profitability of varying economic and genetic parameters. Probably due to the lack of an English translation the paper had less impact than it might. When Soller, Bar-Anan and Pasternak (1966) used discounting methods no mention was made of the earlier paper suggesting that they arrived independently at the need to use discounting methods. They illustrated theoretically how the benefits in milk and beef traits from one round of selection in dairy cattle could be calculated. Essentially they worked out returns in terms of the expected composition of product from an average offspring.

Lindhé (1968) used the alternative approach of calculating the annual genetic gain from a continuing selection programme for dual purpose cattle. He assumed that once genetic progress has been made by a round of selection it is permanently fixed in the national herd and so summed the discounted benefits in perpetuity.

Hinks (1970 and 1971) followed the impact of one round of selection in dairy cattle through two and four subsequent generations (12 - 25 years). Hill (1971) extended the question and considered the capital costs involved in instigating a new scheme for beef cattle. He evaluated a scheme over 20 years including subsequent rounds of selection.

Since the concern of this section is with methodology rather than results, a detailed review of all of the papers published would be of limited value. Miller (1977) provides an extensive review concerned more with actual results (his concern being with identifying the characteristics of optimal plans for the improvement of artificially inseminated cattle populations). The comments below are of a general nature and Tables 2.1 and 2.2 are produced to summarise some of the points of interest.

1. <u>Subject matter of the studies</u>

Two general comments may be made on the papers studied:

- All of the published works were model calculations of a theoretical nature. In no case was an attempt made to review historically an actual breeding programme (as attempted in the present thesis).
- Most of the work done has been in relation to cattle improvement.

2. <u>The viewpoint for appraisal</u>

The majority of the European papers have clearly been concerned with the costs and benefits of national improvement schemes viewed from the nation's point of view (as in the current study). The papers from North America for which Everett (1975) appears to have provided the pattern for most, are mainly concerned with the costs and benefits from a private viewpoint. In the latter ations (12 - 25 years). Hill (1971) extended the question and considered the capital costs involved in instigating a new scheme for beef cattle. He evaluated a scheme over 20 years including subsequent rounds of selection.

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Table 2.1 Investment Appraisals in the Animal Breeding Literature - National Appraisals

Authors	Year	Livestock	Country	Discount Rate (%)
Poutous and Vissac	1962	Cattle	France	N.A.
Soller et al	1966	Cattle	Israel	8
Lindhé	1968	Cattle	Sweden	10
Hinks	1970	Cattle	U.K.	8
Hinks	1971	Cattle	U.K.	5, 7½, 10, 20
Hill	1971	Cattle	U.K.	8, 15, 20
James	1972	Cattle	U.K.	8
Brascamp	1973a	Cattle	Norway	10
Brascamp	1973b	Cattle	Norway	8, 10
Brascamp	1974	Cattle	Norway	10
Cunningham	1974	Cattle	Irish Rep.	10
McClintock and Cunningham	1974	Cattle	Irish Rep.	10
Petersen et al	1974	Cattle	Denmark	8, 10, 12
Cunningham and Ryan	1975	Cattle	Irish Rep.	8 to 16
Lindhé and Holmquist-Arbrandt	1977	Pigs	Sweden	10, 20, 30

N.A. Not available

Table 2.2 Investment Appraisals in the Animal Breeding Literature in Private Appraisals

Author(s)	Year	Livestock	Country	Discount Rate (%)
Oltenacu and Young	1974	Cattle	U.S.A.	10, 15
Everett	1975	Cattle	U.S.A.	0, 8, 10, 12, 14
Van Vleck and Everett	1976	Cattle	U.S.A.	8, 10, 12, 14
Anderson et al	1978	Cattle	U.S.A.	10
McGilliard	1978	Cattle	U.S.A.	10
Van Vleck	1978	Cattle	U.S.A.	0 to 14

case the choice of discount rate becomes less complicated and will be the real cost of capital to the individual concerned (that is, a real market rate). Also uncertainty may dictate further loading to this rate or a shorter cut-off point for evaluating benefits. This distinction in viewpoint is the basis of the division into Tables 2.1 and 2.2, Table 2.2 dealing with private appraisals.

3. Approach

The most common method of measuring benefits was over a given period of years or a fixed number of generations. Studies following the lead of Lindhé estimating the annual genetic gain in a scheme and counting benefits in perpetuity were in the minority (Peterson, Christensen, Andersen and Ovensen, 1974; and Lindhé and Holmquist-Arbrandt, 1977). The period for which benefits were counted varied considerably.

4. Discount Rate

In general no justification has been given for the rates used. Either a single arbitrary rate has been used, for example McLintock and Cunningham's 10%, or Hinks' 8% (perhaps having its origins in the then current UK test discount rate), or a range of several rates so that sensitivity can be tested, as in Hill (1971) and Lindhé (1968). The aim of Cunningham and Ryan (1975) was specifically to examine the effects of the discount rate and time period on calculations. Brascamp (1973b) used a discount rate of 8% for costs and 10% for benefits. This might be justified in terms of a treatment of risk (as described above), but it was not explicitly justified in the paper.

James (1972) in his discussion considered the possible sources of the discount rate and suggested that in some circumstances it may be best to consider the social benefits conferred by the programme and refers the reader to Prest and Turvey (1965).

Hill (1974) gave a general overview of the use of discounting and discussed the possible significance of high discount rates in designing schemes leading to over-emphasis on the short run and genetic variance being reduced as selection intensities rise. Again reference has been made to cost-benefit analysis in the form of Prest and Turvey (1965).

Smith (1978) dealt specifically with the discount rate, identifying the alternative schools of thought in the cost-benefit literature and arguing for lower rates to be used in animal breeding mainly on the basis of the need for real discount rates. Low real rates of return as witnessed in recent years was pointed to as evidence that no real dilemma exists between the SOC and STP approaches (as in HMSO, 1978). Again the dangers of over-intensive selection resulting from high discount rates were mentioned.

5. Conclusions

Comparing the discount rates shown in Table 2.1 and the comments on time period for analysis together with the conclusions of Section 2.1 it may be concluded that:

(a) **Risk:**

Most commonly risk has been adjusted for, at least implicitly, by truncation of benefits rather than loading the discount rate. As described earlier, if the implied reasoning behind doing this is accepted (that is, that after a certain arbitrary point effectively an infinite loading is added to the discount rate for risk) then this method of dealing with risk may be seen as inappropriate. In practice, however, such an argument is less clear-cut.

(b) Discount Rate:

With the exception of Hinks (1971), where lower rates were considered for a test of sensitivity, a minimum rate of 8% per year was used. It is difficult to imagine such a rate was intended as an estimate of the STP rate. Rather the rates used were estimates of the return demanded in the private sector. Few economists would argue against such rates for such a purpose. Totally ignoring STP arguments means that the discount rates used were in general too high. This can have detrimental effects for two reasons:

1. It could lead to a misallocation of resources between projects giving a bias in favour of projects with larger short-term benefits.
2. To the extent that investment is financed from consumption the use of a rate higher than the STP rate as an investment appraisal criterion means that too stringent a test is applied as to whether projects are worthwhile or not. Thus it could be argued that the use of such rates may have led, in general, to an under-investment in animal breeding.

2.3 COST BENEFIT ANALYSIS IN AGRICULTURAL RESEARCH

The purpose of this section is to look into the wider area of economic appraisals in agricultural research in general. This is done for two reasons:

1. As mentioned in Section 2.2 none of the published studies in the animal breeding literature were historical appraisals of actual projects. It may be useful, therefore, to look for guidance on how to tackle such studies to an area where a number of such appraisals have already been undertaken.

2. It is hoped to place the current study into context with work done within this wider area.

To these ends, consideration is given to three aspects of this literature:

1. The general approach
2. The areas studied
3. The scale of results reported.

Further reference to the papers considered here on points of greater detail will be made later in the thesis. First, however, the relevance of this area for comparison is discussed.

The Relevance of Appraisals in Agricultural Research

A number of papers have been published documenting cost-benefit studies in the area of agricultural research. The use of the word "research" in relation to these studies is perhaps misleading. For example, it can easily be argued that the production of a new variety of cereal crop is a development project rather than research. The process of search is similar to that seen in animal selection: measurement of a large sample from a test population to identify superior stock for breeding. The scientific principles upon which this selection is based are well defined; the development of new strains has almost become a routine application of these principles. Certainly the multiplication of superior stock so that it can be used commercially, which must account for a significant amount of the costs involved in producing a new strain, is not a research activity. Alternatively with a new type of farm machinery, or a new agricultural technique, the end results in terms of benefits at commercial farm level (which are the benefits measured in these studies) seldom result solely from research efforts. Commonly the final value of the research is only seen after what might be termed a development stage which may involve quite routine work and often involves considerable cost. It is not proposed to discuss the definitions of the terms "research" and "development" here. The point of raising this issue is to suggest that these studies are comparable with the pig improvement work which is the subject of this thesis and which animal breeders would not describe as research work, but as a development or application of well established and proven methods.

2.3.1 General Approach

Basically two alternative approaches have been taken to measuring the benefits of past investment:

1. Production Function Approach

This basically involves a form of multiple regression analysis in which changes in production are treated as a function of variations in a number of input variables. These might include for example, the utilisation of land, irrigation, fertilisers and some measure of the introduction of a new technology, such as a percentage of the crop produced from a new variety (in some instances research expenditure was taken as the variable of which the significance was measured). Examples of this type of approach would be Griliches (1964) appraising aggregate agricultural research, or Peterson (1966) on poultry research.

2. Index Number Approach

This uses estimates of productivity gains from a new technology to measure the downward shift in the supply function arising from that new technology. Examples of this type of study might be Griliches (1958) on hybrid corn, or Schmitz and Seckler (1970) appraising the development of a tomato harvester. If the sort of models reported in the papers of Table 2.1 were retrospectively applied to quantify benefits, these would fall within this category.

While describing a logical functional form for a production function might be relatively simple the problem of obtaining adequate statistics for all of the necessary input variables is less so. In terms of the current study the type of cross-sectional data available from Griliches (1964) (from different States in the US) would not be available in looking at pig improvement in Great Britain. Using time series data it is unlikely that the effects of genetic improvement could be satisfactorily isolated from the many other "trends" affecting the pig industry. Indeed it might be expected that the approach would have more success in dealing with a more general subject (such as all technological change on a particular agricultural sector as reported in some studies) than something as specific as genetic improvement in an industry that has seen improvement in housing, marketing, health and nutrition. For these reasons it was concluded that the second type of approach was most appropriate for the current study. It is attempted, therefore, to take estimates of the genetic improvement and try to estimate its impact on the industry rather than looking at changes in the efficiency of the industry and attempting to apportion them between genetic progress and other factors.

2.3.2 Scope and Results of Published Studies

Table 2.3 is given to summarize the areas investigated and the scale of benefits reported. The internal rate of return is given as this was the most commonly used criteria. Also, while bearing in mind the criticism of this technique made earlier, internal rates of return allow some simple comparison of results to be made without the need to adjust results for the overall scale of investment or the currency involved. Studies where internal rates of return were not quoted have been omitted from the Table.

While Table 2.3 does not record all of the work published in this area, it does include the majority of such studies and is sufficient to illustrate the range of subjects investigated. Where "aggregate" is used as the commodity name the authors have

Table 2.3 Published Cost Benefit Studies of Agricultural Research Activity

Author		Date	Country	Commodity	Time Period	IRR (%)
Griliches		1958	USA	Hybrid corn	1940-55	35-40
"		"	"	Hybrid sorghum	1940-57	20
"		1964	"	Aggregate	1949-59	35-40
Peterson		1967	"	Poultry	1915-60	21-25
Evenson		1968	"	Aggregate	1949-59	47
"		1969	South Africa	Sugarcane	1945-58	40
"		"	Australia	"	"	50
"		"	India	"	"	60
Ardito Barletta		1970	Mexico	Crops	1943-63	45-93
Ayer and Schuh		"	Brazil	Cotton	1924-67	77+
Schmitz and Seckler		"	USA	Tomato Harvester	1958-69	16-46
Evenson and Jha		1973	India	Aggregate	1953-71	40
Evenson and Kislev	(a)	1975	Developing countries	Wheat	1948-68	27
"	(a)	"	Developed countries	"	"	19
"	(a)	"	Developing countries	Maize	"	11
"	(a)	"	Developed countries	"	"	9
"	(a)	"	Developing countries	Aggregate applied research	1955-68	42
"	(a)	"	Developed countries	"	"	21
Hayami and Akino	(b)	"	Japan	Rice	1915-50	25-27
"	(b)	"	"	"	1930-61	73-75
Hertford, Ardila, Rocha and Trujillo	(b)	"	Colombia	"	1957-72	60-82
"	(b)	"	"	Soyabeans	1960-71	79-96
"	(b)	"	"	Wheat	1953-73	11-12
"	(b)	"	"	Cotton	1953-72	None
Khalon, Saxeman, Bal & Jha	(b)	"	India	Aggregate	1960/61-1972/73	63
Peterson and Fitzharris	(b)	"	USA	"	1937-42	50
"		"	"	"	1947-52	51
"		"	"	"	1957-62	49
"		"	"	"	1967-72	34
Flores-Moya, Evenson and Hayami		1978	Philipines	Rice	1966-75	26-28
"		"	"	" *	"	45-71

* Including benefits for rest of world

(a) As reported in Evenson and Kislev (1975)

(b) From a conference reported in Arndt, Dalrymple and Ruttan (1975).

attempted to evaluate investment in all areas of agricultural research for the country involved. It may be noted that in only one instance did an author deal with a livestock industry in isolation (Peterson, 1967) and in that case concern was with all aspects of improved efficiency in the industry, including nutrition, housing and genetic improvement.

Clearly from Table 2.3 it can be seen that the reported benefits have generally been high. Bearing this in mind two comments are perhaps worth making:

1. It may be argued that these studies give a biased impression in that in looking at individual past projects authors naturally pre-select projects that have been successful. Griliches (1958) acknowledged the subjects of his attention were known successes and raised the question of the many "dry holes" where resources were used for research and development without significant success. This criticism is clearly not valid against studies considering aggregate research (eg Griliches, 1964) though it might be argued that British pig improvement was selected as a "proven" scheme.

2. Webster (reported in Arndt, Dalrymple and Ruttan, 1975) suggested that many studies have arrayed benefits against only direct research costs omitting or reporting only in part the costs of implementation. In the current study it is attempted to include all relevant costs including an allowance for pure research.

In commenting on the results reported, Arndt et al conclude that while many of the studies available are open to some possible criticism "Nevertheless the overall robustness of the return figures does not appear to be in doubt".

The degree to which authors have attempted to deal with the question of the distribution of benefits and costs has varied and many authors have not attempted to take any account of this issue. Further comment will be made regarding distributional effects in Chapter 9.

Chapter 3

A DESCRIPTION OF PIG IMPROVEMENT WORK IN GREAT BRITAIN AND SOME OTHER ASPECTS OF THE PIG INDUSTRY

Before considering the benefits and costs of pig improvement in Great Britain some description of the pig industry and the mechanisms through which genetic progress is achieved is appropriate. Essentially the main concern of pig improvement work has been to select genetically superior breeding stock for use by the industry as a whole. This work has been carried out both by statutory organisations and by independent breeding companies. Each is dealt with in turn.

3.1 PUBLIC INVESTMENT IN PIG IMPROVEMENT

Public investment in pig improvement began in 1957 with a progeny testing scheme (based on the Danish progeny testing system) operated by the National Pig Progeny Testing Board (NPPTB), founded in 1955. This scheme was not very effective for a number of reasons (Smith, 1965):

1. The progeny testing system was slow and allowed only a small number of sires to be tested at any one time (about 125 boars per year).
2. There was no restriction on which breeders might enter boars for testing apart from Breed Society membership, so that influential breeders with the best stock did not have priority.

3. There was little selection of boars on the basis of the progeny test results.

In 1963 the NPPTB was integrated with the Pig Industry Development Authority (PIDA) which had been formed in 1957. In 1966 PIDA replaced the progeny testing scheme by the current combined performance testing scheme. This involves selection of boars based on their own performance rather than on that of their progeny. PIDA in turn, was incorporated into the Meat and Livestock Commission (MLC) when it was formed in 1968. This organisation has current responsibility for the central (testing station) performance testing scheme and for other pig improvement services. Besides the MLC's work certain relevant advisory and research work is carried out by other bodies. This work is discussed in Chapter 7.

3.1.1 The Role of the MLC

In principle the MLC receives money to undertake a wide range of improvement work, research, development and other activities. This money comes mainly from levies on slaughtered animals, but there are some charges for services given and some agency payments from the Government. The aim of the work is to assist pig producers and meat traders to increase the efficiency of the industry as a whole. Paths to progress can roughly be categorised into two broad groups: through genetic improvement, and through improved husbandry and other practices within the industry as a whole. The MLC concerns itself with both paths. While this study is interested mainly in genetic improvement, it should be noted that management and husbandry techniques on farms and the technology of the meat trade and traders may also have been improving appreciably over the same period. Regarding genetic improvement, there are two main aspects:

1. Testing and selection work to identify and breed from superior pigs, both as individuals and as populations.
2. To try to ensure that such superior strains are brought into effective use in the national herd.

The main operations of the Commission in these respects are:

1. The central performance testing scheme inherited from PIDA.
2. A national on-farm testing scheme.
3. The commercial product evaluation (CPE) test for the comparative testing of hybrid pigs from independent breeding companies.
4. An artificial insemination service.

3.1.2 Central Performance Testing

The system has remained virtually unaltered since its inception in 1966 and is the largest scheme for pig improvement the MLC operates. A more detailed description of the scheme with supporting arguments is presented in PIDA, 1965. Essentially the scheme tests at central testing stations the performance of boars and siblings from a restricted group of "nucleus" herds in order to identify superior boars for breeding. The scheme was envisaged as working like a pyramid with a small number of high quality herds at its apex (the nucleus herds) generating genetic progress and passing this on to the commercial industry should be noted that management and husbandry techniques on farms and the technology of the meat trade and traders may also have been improving appreciably over the same period. Regarding genetic improvement, there are two main aspects:

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Current testing accommodation is for 2,400 boars and 3,200 siblings (see below) at any one time at four stations (those previously used for progeny testing). The possible intake of the stations is about 5,000 boars per year. In the late 1960s and early 1970s this figure was achieved but more recently the figure has dropped to nearer 4,000 boars.

A group tested consists of two boars, and two siblings (one castrate and one gilt (young female) from the same litter). The sibling information contributes little to the accuracy of the boar test for growth traits but is important for carcass traits, since the live boar cannot be slaughtered and his carcass measured. For veterinary reasons it was thought undesirable to use indoor controlled environment housing for testing boars which would be returned to farms for breeding. Covered outdoor kennel-type boar accommodation (with a free flow of fresh air over the pigs) was therefore built in 1965-66; the previously existing accommodation is used for the siblings which are slaughtered at the end of the test.

Six characteristics are considered as objectives in selections:

1. Daily Gain:

   The live-weight gained per day measured in the central test over the range 18 to 90 kgs.

2. Food conversion ratio:

   The ratio of weight of food eaten to live-weight gained.

3. Killing out percentage:

Dead carcass weight as a percentage of live-weight (with body organs removed).

4. Trimming percentage:

Carcass weight after trimming as a percentage of dead carcass weight (with head, feet, tail and some internal fat removed).

5. Eye muscle area:

The area of cross-section of the longissimus dorsi (the large oval muscle in the pig's loin chop).

6. Lean percentage:

The estimated percentage of lean tissue in the final trimmed carcass.

All the traits measured are combined into a points score (a selection index) intended to indicate as accurately as possible the breeding value of the performance tested boar for these traits. The selection index takes account of the economic value of each trait (which will be considered in Chapter 6), and of the heritabilities and correlations for the different traits. The merit of boars is always judged in relation to their contemporaries tested at the same time, by breed and by station, and actual figures for performance are not provided. The contemporary comparison method is used to reduce differences due to differences in environmental conditions over time and location.

The selection index is calculated for each boar from the performances of the boar and of its siblings. The average index score for all boars being tested is maintained at 100 points

3. Killing out percentage:

   Dead carcass weight as a percentage of live-weight (with body organs removed).

4. Trimming percentage:

   Carcass weight after trimming as a percentage of dead carcass weight (with head, feet, tail and some internal fat removed).

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The selection index is calculated for each boar from the performances of the boar and of its siblings. The average index score for all boars being tested is maintained at 100 points and the standard deviation at 35 points. Boars scoring 90 points or less are slaughtered (approximately 40%) and boars scoring above 90 are offered back to breeders. The boars with the highest index scores are used in the breeding herds or in artificial insemination, while the poorer boars go to commercial farms to sire commercial progeny.

Trends in the yearly records may include non-genetic effects due to changes in nutrition and disease and other factors. Thus they are variable and unreliable and are not used to estimate genetic trends. Genetic progress is measured through comparisons with pigs from two genetic control herds each of 16 sires and 32 dams per generation (Landrace at Wye College and Large White at the University of Newcastle). In these control herds, breeding is at random but with a son from every sire and a daughter from every dam, so that there should be little genetic change over the years. Samples of pigs from these herds are tested at the central testing stations so the genetic improvement in the pigs from the testing herds can be measured.

3.1.3 On-Farm Testing

An on-farm testing system has been in operation since 1960. The objective is to improve the selection of females in the nucleus breeding herds, to complement boar selection based on central testing. Some 20% of pigs tested are boars (A Landon, personal communication). Membership of this scheme is not closed and the method is popular with many breeders as it is simple, cheap and the health risks are minimal. It is a less accurate test than the central test but enables large numbers of breeding stock to be evaluated. There is no control over the use of this testing and no requirement to cull pigs with low scores. It is therefore difficult to assess the influence of this operation though some comments regarding the value of this work will be made in Chapter 7.

3.1.4 Commercial Product Evaluation (CPE)

CPE began in 1972 and aims to compare the overall economic worth of pig stocks from different breeding companies. It works by purchasing a random sample of 30 breeding females and 5 males at multiplier level so producing pigs equivalent to the commercial product from the breeding company stocks. Measurements are taken on litter performance and on progeny growth-carcass performance. These are used to compare the values of the breeding pigs on the market. The tests show the qualities of different breeding companies' pigs relative both to each other and also relative to a sample of improved nucleus Large White pigs. Each test takes 2½ years to complete, one test being started each year. Results are now available for five tests. The results of these tests will be used in Chapter 4.

3.1.5 Artificial Insemination

An artificial insemination (AI) service has been offered by the MLC since 1968. Its main value is in providing highly selected sires for use across many herds. Unfortunately AI leads to lower numbers of pigs born per litter than with natural service and therefore it is not widely used in the commercial industry (D Steane and D Guy, personal communication). The possible uses of AI will be considered in Chapter 5. The MLC is not the only organisation to run an AI service. A small service is run by the Ministry of Agriculture, Fisheries and Food and others by independent companies.

3.2 THE INDEPENDENT BREEDING COMPANIES

A number of independent breeding companies have arisen since 1966. Depending on the definition of a company the number may range from 10 to 20 or 30. Many started as MLC scheme nucleus herds. Probably all have some genes from centrally tested stock present in their herds. Many still have contacts with the MLC to a greater or lesser extent and some still test centrally. The relationships with the MLC's work, and overlaps in the sales data available and use of stock by the industry, make it essential that these breeding companies be included in the study.

3.3 THE PIG INDUSTRY

The aim of this section is to give a brief description of some aspects of the pig industry including one or two points of particular relevance to the current study.

3.3.1 The Scale of the Pig Industry

Figures for the UK show in 1975-76 pig production accounted for approximately 10% of total agricultural output in money terms and was worth over £500 million (value of sales) to producers (MAFF, 1977). Table 3.1 illustrates the production of pork and bacon and ham in tonnes for recent years compared with the other major carcass meats. In terms of animals slaughtered, upwards of 12 million pigs have been slaughtered per year since 1968 in Great Britain (figures for the United Kingdom, which includes Northern Ireland, are approximately one million higher; MLC, 1978 and 1981). More detailed figures for slaughterings will be given in Chapter 5. The future size of the industry is difficult to forecast, but with current economic and political conditions a contracting industry, without a very major change in consumption habits, is unlikely. Some forecasts will be used in Chapter 5.

3.3.2 Self Sufficiency

Table 3.1 shows that in recent years the UK has been virtually self sufficient for fresh pork. All of the other major carcass meats, even bacon and ham, have lower rates of self sufficiency. Future developments will be commented on in Chapter 9.

3.3.3 Markets for Pig Meat

The distinction between pork, and bacon and ham may be taken as an indication that the pig industry does not supply one homogenous product. It should be noted that generalisations made in the current study with respect to pork may not hold for bacon and ham where the processing and international trade involved make the situation more complex. In practice slaughter pigs are raised to different weights for different sectors of the market. For

Table 3.1 Scale and Self Sufficiency of Major UK Meat Industries

	Thousands of Tonnes of Meat							
	1973	1974	1975	1976	1977	1978	1979	1980
Beef and Veal								
Production	887	1086	1219	1057	1002	1028	1047	1098
Imports	337	294	247	247	294	307	309	260
Exports	105	82	142	101	88	95	92	152
Total New Supply	1110	1299	1324	1207	1208	1249	1270	1220
Self Sufficiency (%)*	79	84	92	88	83	82	82	90
Mutton and Lamb								
Production	236	253	264	243	223	228	231	270
Imports	266	213	244	226	219	226	208	192
Exports	31	30	39	33	45	41	41	37
Total New Supply	472	436	418	435	401	403	404	425
Self Sufficiency (%)*	50	58	56	56	45	57	57	64
Pork								
Production	683	695	572	584	650	634	697	681
Imports	20	7	17	12	16	39	37	39
Exports	17	26	8	11	17	13	19	17
Total New Supply	686	676	581	583	651	656	716	704
Self Sufficiency (%)*	99	103	98	100	100	97	97	97
Bacon and Ham								
Production	252	243	210	222	219	214	211	209
Imports	314	288	273	269	279	312	307	303
Exports	2	4	2	2	2	2	2	4
Total New Supply	564	527	482	489	496	523	516	507
Self Sufficiency (%)*	45	46	44	45	44	41	41	41

* Production as a percentage of Total New Supply.

Source: MLC (1978 and 1981)

pricing systems four weight ranges are commonly referred to. These ranges, together with the approximate proportions for Great Britain of stock slaughtered in each range, are as shown in Table 3.2. It may be noted that very few pigs are raised to the heaviest weight range. It may also be noted that names used for the different weight ranges do not signify that a particular weight range is used solely for one purpose. That is, it is not appropriate to assume that all of the pigs raised to the bacon range will be used for bacon. The different ranges to which pigs are raised may be significant in the estimation of total benefits and will be returned to in Chapter 8.

3.3.4 The Structure of the Pig Industry

The structure of the industry has not been static in recent years. The trend has been for an increasing concentration in the industry with herd sizes increasing. D H Smith (personal communication) estimated an average of approximately 5,000 holdings per year leaving the industry over the 20 year period up to 1974. While the figure is now much lower this decline in numbers still continues (approximately 2,500 holdings leaving the industry from June 1977 to June 1978; MLC, 1980). If a herd size of 1,000 pigs is taken as a cut-off point, the largest 5.5% of the herds contained 48% of the pigs in Great Britain (MLC, 1980). The industry still, however, consists of many producers each too small to significantly affect the total industry. In 1978 a total of 27,096 holdings were reported as keeping some pigs, with 94% of them having 100 or more pigs each (MLC, 1980).

Table 3.2 **Weight Ranges of Slaughter Pigs in Great Britain**

	Live-weight (Kgs)	Percent
Pork	40 - 67	22
Cutter	68 - 82	21
Bacon	83 - 101	55
Heavy	102	2
Approximate average	80 Kgs	

Source: Figures from MLC classification records (T Fowler, personal communication).

3.3.5 Fluctuations and Trends

A wide range of factors cause fluctuations in the numbers of stock slaughtered and the prices of pig meat. These fluctuations are ignored in the current study because:

1. For years up to 1979 actual numbers of stock slaughtered will be used to calculate benefits (see Chapter 5).

2. For years after 1979 the fluctuations will be ignored by "smoothing out" projections (Chapter 5). The high years should balance the low.

3. The base year for calculations in terms of monetary values, 1977, was not an untypical year so that taking values from that year should not significantly under or over-state benefits.

3.3.6 Northern Ireland

The study confines itself to Great Britain, that is excluding Northern Ireland. This is simpler and convenient because:

1. Northern Ireland has its own breeding programmes which are independent (Steane, personal communication).

2. Figures for Northern Ireland are complicated by cross-border trade with Eire.

Chapter 4

GENETIC PROGRESS ACHIEVED

Information on the genetic progress achieved in the improvement herds is taken from two sources:

1. The control herd comparisons in the central test are used to estimate the genetic progress made in the central test nucleus herds.

2. The commercial product evaluation results are used to show the progress made by the independent breeding companies relative to the test nucleus breeders.

Before consideration of this information however a basic assumption must be noted: that no effective progress would be made without investment. Reliance for this must be placed on personal communication with animal geneticists experienced in the field (D E Steane, C Smith). They argue that in the past farmers' selection had been based largely on subjective assessment of conformation which could not be expected to lead to any real improvement in commercial performance. To create improvement investment must be made in testing and selection. It is possible that, in the absence of national investment in testing and of the independent breeding companies, private breeders would have done their own testing and selection, but this would have required investments, probably of the same scale.

4.1 CONTROL HERDS

Genetic progress in the central testing scheme is measured through comparisons with pigs from two genetic control herds (see Chapter 3). Improvement in pigs from the nucleus herds is estimated as the linear regression on time (in years) of their superiority over the control pigs. Results for the period 1969-77 are available (D Jones, personal communication) showing improvements in each trait, and these are given in Table 4.1. The acceptance of these estimates depends on certain assumptions:

1. That the control herd method of measuring progress is accurate.
2. That the progress estimated by the comparison is achieved by the commercial farmers in practice.
3. That other traits not directly selected for are unaffected (or at least, are not adversely affected).

4.1.1 A Critique of the Control Herd Comparison

Possible criticisms of the control herd comparison may be seen in Standal (1979). Standal compared estimates of genetic progress for Norwegian pigs with estimates from an alternative source (comparing the change over time in the performance of successive progeny groups of the same AI sires), and found the control herd results to be unrealistic. He suggested possible reasons as: chance genetic drift or natural selection within the small control herds, changes in pre-test environment due to the small numbers of animals tested. Estimates from the British control herd comparison appear more reliable however, both being of a similar scale to those estimated by Standal's alternative method and having much lower standard errors. Certainly a far greater number of control pigs have been tested in Britain. Jones (1979) considered two changes in pre-test environment in the British control herds: in age at weaning and in creep feed (used for the early feeding of piglets). He found that weaning practices had had no effect on the estimates of progress and that there is insufficient evidence regarding creep feeds to draw conclusions. It is impossible to say whether genetic drift or natural selection have been significant.

To obtain the most accurate estimate of progress possible, data from the longest period available is taken and it is assumed progress has been even over the period. Some consideration of the validity of this assumption will be given in the sensitivity analysis (Chapter 8).

4.1.2 Achievement of Progress at Commercial Farm Level

The full benefits suggested by the control comparison may not be obtained at the commercial farm level. Two possible factors which may reduce benefits are:

1. Commercial Diets

R Fawcett (personal communication) has suggested that any economic comparison should be made with each type of pig (improved and control (or unimproved)) on the production system, such as diet and feeding regime, which allows it to maximise profit. The genetic response estimates in Table 4.1 come from pigs fed to appetite on a high protein diet, and this favours the improved pigs. A comparison on a poor quality diet fed restrictively might reduce the estimates of benefit since the improved pigs may be unable to express their genetic potential. Aspects of this comparison will be discussed later (Chapter 8 in the sensitivity analysis) using results from the Edinburgh Pig Model (Whittemore and Fawcett, 1976).

2. <u>Pig Slaughter Weight</u>

In the central test and in the economic evaluation (see Chapter 6) an average slaughter weight of 90 kg is used. However, in commercial practice pigs are killed at different weights for different markets (see Chapter 3). This factor will also be considered in Chapter 8.

4.1.3 Other Traits

While the six traits in Table 4.1 were the main objectives in selection and in the progress measured, they do not represent all aspects of pig production and profitability. For example eye muscle area is of questionable economic importance. On the other hand, other traits might have been included. Since the issue here is what progress has been made, not what progress might have been made by selecting for other traits, it might seem appropriate to limit assessment to the six traits listed. Such an exercise might overstate the benefits however, if selection has brought about detrimental changes in other traits. Some traits which may be considered are:

1. <u>Mature Weight</u>

Selection for leanness in the slaughter generation may lead to pigs with heavier weights as adults. Thus additional costs

Table 4.1 Estimates of long-term annual genetic progress in Nucleus Herds

Trait	Estimated genetic change (units/year)	Standard Error of Estimate
Feed conversion	-0.0269	0.00325
Daily Gain (kg)	0.00491	0.000989
Eye muscle area (cm^2)	0.266	0.034
Killing out %	0.109	0.0288
Trimming %	0.082	0.00292
Lean in side %	0.683	0.0656

Pooled results for Large White and Landrace control herd comparisons, 1969 to 1977, from D W Jones (personal communication).

would be incurred by the commercial farmer in feeding breeding stock to reach and maintain these greater weights. Consideration will be given to this factor in the sensitivity analysis (Chapter 8).

2. Litter Size

Litter size was not included in the selection index, despite its high commercial value, because of the low heritability of reproductive traits. The existing evidence suggests that selection for performance traits does not affect reproductive traits (Morris, 1975; Hetzer and Miller, 1970; and Legault, 1971).

3. Muscle Quality

An unfavourable association of muscle quality with increased lean percentage may have led to poorer meat quality. This was first suggested as a result of the knowledge that the Pietrain breed, which was known to be leaner than the other breeds, also had problems with muscular quality. Freeden (1973) reviewed the data on the subject. He concluded that most of the evidence indicating a detrimental correlation between leanness and meat quality was based on Landrace pigs. Hetzer and Miller with Duroc and Yorkshire, and Freeden and Lacombe, found no indication of adverse meat qualities resulting from intense selection.

4. Longevity

There is no evidence to suggest that this has been adversely affected (D Steane, personal communication).

4.2 COMMERCIAL PRODUCT EVALUATION

In addition to the direct effects of the nucleus herd improvement, the improvement brought about in the national herd by the independent breeding companies must also be considered. The performance of pigs from these private companies has been tested alongside pigs from the national scheme since 1972 by the MLC in their Commercial Product Evaluation (CPE) described in Chapter 3.

The tests are designed to evaluate the stock available to commercial producers in as near commercial conditions as possible (compatible with the need to obtain detailed records and good contemporary comparisons). The stock is purchased from the multiplier herds of the breeding companies and from the equivalent level for Large Whites in the national scheme. The progeny are evaluated to three slaughter weights (pork, bacon and heavy) and two feeding regimes (restricted and ad libitum). Carcasses are evaluated in detail after slaughter. Five sets of test data are available for intakes from 1972 to 1976, with results 1975 to 1979. Through comparison with the sample of Large White pigs tested at CPE, the relative merit of pigs from the breeding companies can be derived.

The average values for five of the central test index's economic traits (results for trimming percentage are not given) were calculated, pooling the results for the weight ranges, feeding systems and for the five sets of CPE results. The results are shown in Table 4.2, first unweighted and then weighted by the proportions of the total market held by each company, as estimated by the MLC (D E Steane, personal Communication).

Table 4.2 Average MLC commercial product evaluation (CPE) results from 1975 to 1979 for ten breeding companies (where present) and for Large Whites, with unweighted and weighted company average

TRAIT	COMPANY										Average (unweighted)	Average (weighted by estimated percentage sales)	CPE Large White
	1	2	3	4	5	6	7	8	9	10			
Daily gain (gm)	709	731	744	748	734	725	720	744	717	742	731	737	738
Feed conversion ratio	3.16	3.02	3.06	2.89	2.97	3.05	3.03	2.96	3.10	2.93	3.02	2.97	2.96
Killing out %	75.2	75.4	74.8	75.2	74.8	75.7	75.4	75.1	75.5	75.4	75.3	75.0	75.4
Lean % in rump back	46.8	47.4	46.8	49.3	48.6	46.7	47.3	48.3	45.6	48.8	47.6	48.5	48.0
Eye muscle area (sq. cm)	32.2	32.3	31.9	33.2	32.4	31.9	32.3	33.0	31.2	32.9	32.3	32.6	32.3

Direct comparison of the Large White sample with the company pigs would be inappropriate since the company pigs are crossbreds while the Large Whites are purebreds. This is important because:

1. of heterosis (hybrid vigour), which would produce a better performance for some traits in crossbred pigs compared with purebreds; and
2. the central test results suggests that the Large White breed is, in general, superior to the Landrace breed with which it is principally crossed.

In Table 4.3 the average performances (1975 to 1978) of the two main breeds in the central test (1975-78) are given. Estimates of the heterosis effects are taken from a comprehensive review of the literature by Sellier (1974). The estimated percentage differences in performance of the two major crosses from the purebred Large White for each trait are derived as shown in the Table. The common practice would be to cross either purebred Landrace (L) or Large White (LW) boars with crossbred (LXLW) females to produce slaughter animals. These percentage figures are then used to derive estimated performance figures for the crossbreds based on the Large White results from the CPE test. These are shown in the final two columns.

The results are compared in Table 4.4 with the company averages. The MLC index's economic values for the station testing work are used to evaluate the economic differences in value per pig for different stocks (an examination of the value of progress in each trait will be given in Chapter 6, but the MLC values are sufficient for comparison at this stage).

Table 4.3 Estimated Commercial Product Evaluation (CPE) performance of LW (LWXL) and L (LWXL) Pigs: estimated from MLC combined central test (CT) results 1975-78, and heterosis estimates (Sellier, 1976)

TRAIT	Combined Tests (CT)		Estimated Heterosis %	Commercial Product Evaluation (CPE)		
	Large White (LW)	Landrace (L)		Actual LW	Estimated* LW (LWXL)	Estimated L (LWXL)
Daily gain (gm)	794	788	5	738	755	752
Feed conversion ratio	2.51	2.62	3	2.96	2.95	3.01
Killing out %	80.0	78.8	0	75.4	75.1	74.6
Trimming %	85.0	85.2	0	-	-	-
Lean %	57.4	56.5	0	48.0	47.9	47.4
Eye muscle area (sq. cm)	33.8	32.3	0	32.3	31.9	3.12

$$* \; LW(LWXL) = LW_{CPE} + \tfrac{1}{4}(L_{CT} - LW_{CT}) + \tfrac{1}{2}\left(\frac{\text{Heterosis \%}}{100}\right)(LW_{CPE})$$

$$L(LWXL) = LW_{CPE} + \tfrac{3}{4}(L_{CT} - LW_{CT}) + \tfrac{1}{2}\left(\frac{\text{Heterosis \%}}{100}\right)(LW_{CPE})$$

Table 4.4 __Estimated value per pig of pigs from Crossbred (hybrid) Females from Breeding Companies Relative to Those from MLC Multiplier Nucleus Herds__

TRAIT	Economic Value (p)	CPE LW	CPE Company Average (Unweighted)	CPE Company Average (Weighted)	CPE Best Company	Estimated*	
						LW(LWXL)	L(LWXL)
Daily gain (gm)	0.953	738	731	737	748	755	752
Feed conversion ratio	-864	2.96	3.02	2.97	2.89	2.95	3.01
Killing out %	63.0	75.4	75.3	75.0	75.2	75.1	74.6
Lean %	55	48.0	47.6	48.5	49.3	47.9	47.4
Eye muscle area (sq. cm)	3	32.3	32.3	32.6	33.2	31.9	31.2
Deviation from LW in value per pig (p)		0	-86	-6	+132	-1 (+57)ƒ	-98 (-46)ƒ

* From Table 2.

ƒ Using best three nucleus herds per breed (1971-78).

The results for the best of the companies are clearly far superior to either of the average results quoted and also to the Large White sample and crossbred estimates. Results for different nucleus herds also vary considerably however, as can be seen from the estimates of the comparative figures for the three best nucleus herds given at the bottom of the last two columns of Table 4.4. For the purposes of the present study average figures were taken.

The unweighted company average figures for these traits suggest that the average economic value of company produced pigs is significantly poorer than the best crossbreds from nucleus pigs (LW (LWXL)) and approximately on a par with the poorer crossbreds (L (LWXL)). The sales weighted average should give a more accurate estimate of the economic value of pigs available from company sources, however. Comparisons based on this average suggests that the value of company pigs is remarkably similar to that of the best crossbreds from nucleus sources. It is therefore felt justifiable to take the progress of the companies to have been similar to that in the nucleus herds for the purpose of the calculations below. Since more precise figures on the progress achieved by the companies (as quoted for nucleus pigs from the control herd comparison) are not available and attempting to partition benefits between the two sources of improvement would be unrealistic, this simplification is very convenient when attempting to evaluate pig improvement in Great Britain as a whole.

Chapter 5

THE DISSEMINATION OF PROGRESS TO THE NATIONAL HERD

The purpose of this chapter is to consider the impact on the commercial herds of the genetic improvement described in Chapter 4. A number of alternative pathways may be identified through which the improvement achieved in the nucleus herds (and breeding companies) is disseminated to the commercial herds. The approach adopted is to estimate the impact of each of the main pathways. There are two aspects to this:

1. The proportion of the final slaughter stock affected by each pathway must be estimated.
2. The length of time before the progress achieved in the nucleus herds (and company herds) is seen in the commercial herds must be estimated (the improvement lag).

Each is considered in turn. In Section 5.1 the main pathways are outlined and the proportions of the commercial industry affected by each pathway are estimated. The approach used is to take information on the sales of improved breeding stock and to consider the subsequent use of that stock. Some simplifying assumptions are necessary. Sales figures are available for recent years from the MLC broken down by type of herd (nucleus, multiplier and breeding company) and by type of pig (boar, pure-bred gilt and crossbred gilt). Unfortunately the full set of figures for each year is not available. Figures showing artificial inseminations supplied to the industry are also available from the MLC.

The use of breeding stock (and inseminations) once sold is not recorded, but some estimates of the destinations of that stock are available. Certain assumptions regarding the use of that stock can then be made which should be fairly accurate (D Steane, personal communication). These assumptions relate to the different pathways through which dissemination occurs. It is therefore possible to estimate the proportions of the breeding stock present in the commercial herds that have come from each of the pathways identified.

In Section 5.2 the improvement lags are considered. Bichard (1971) examines the way in which additive genetic improvement made in a nucleus population is passed to successive levels in a multiplication system (as here). He describes alternative models or pathways involving two or three tiers, and illustrates how the improvement lag between any two tiers in time approximates to a simple function of the annual progress being made in the nucleus level. He then illustrates how this lag may be calculated for alternative pathways and goes on to consider the scope for reducing the lag within the context of British livestock production. The methods of Bichard are used to estimate the average lags in years for each of the various pathways described in Section 5.1.

In Section 5.3 the figures from Sections 5.1 and 5.2 are combined to estimate the benefits from the different pathways, year by year, in terms of expressions of the annual rate of progress per pig per year achieved in the improvement herds. The valuation of benefits is the subject of Chapter 6.

5.1 THE PROPORTIONS OF THE INDUSTRY AFFECTED BY DIFFERENT DISSEMINATION PATHWAYS

Consideration of the proportions of the industry following alternative pathways for the dissemination of genetic improvement is carried out in four stages:

1. A number of assumptions are stated which serve to describe the alternative dissemination pathways.
2. Methods are described for estimating the numbers of breeding stock present in the commercial herds in different years resulting from each of these pathways.
3. The data available is described.
4. The proportions of the industry affected in different years by the different pathways are estimated.

5.1.1 Assumptions regarding the alternative dissemination pathways

The following assumptions are made:

1. Most crossbred gilts sold by nucleus, multiplier and breeding company herds to the commercial industry are used as parents of slaughter stock.
2. Most farmers buying such stock will continue to buy such stock; they will obtain most of their replacement sows by buying such stock. The improvement in their herds will thus be permanent and accumulative.
3. Crossbred gilts will be mated with boars also bought from

improved sources. The dissemination pathway assumed, therefore, is as shown in Figure 5.1. This pathway is described and discussed in relation to pigs in Britain by Bichard (1971). It has grown in importance with the independent breeding companies and for simplicity will be referred to hereafter as the "Company" style pathway.

4. Purebred gilts from nucleus herds are used by commercial producers to produce homebred crossbred gilts; that is, essentially the same system as above with the multiplier function combined with the commercial herd. Again it is assumed all boars purchased are also improved stock.

5. The boars sold from nucleus and multiplier herds to the commercial herds will represent sales:

   a. For use with the gilts described above.

   b. For use in the alternative dissemination pathway in which only boars are passed down, as in Figure 5.2. Bichard (1971) also describes this pathway and identifies it as the traditional structure in the pig industry. Hereafter it will be referred to as the "Traditional" style pathway.

6. Purebred gilts will remain in use for breeding, on average, two years (four litters), crossbred gilts 2.5 years (five litters), and boars two years (D Steane, personal communication).

7. Each litter from the purebred gilts will produce, on average, two crossbred gilts for use in breeding slaughter stock (D Steane, personal communication).

Figure 5.1 The "Company" style Dissemination Pathway

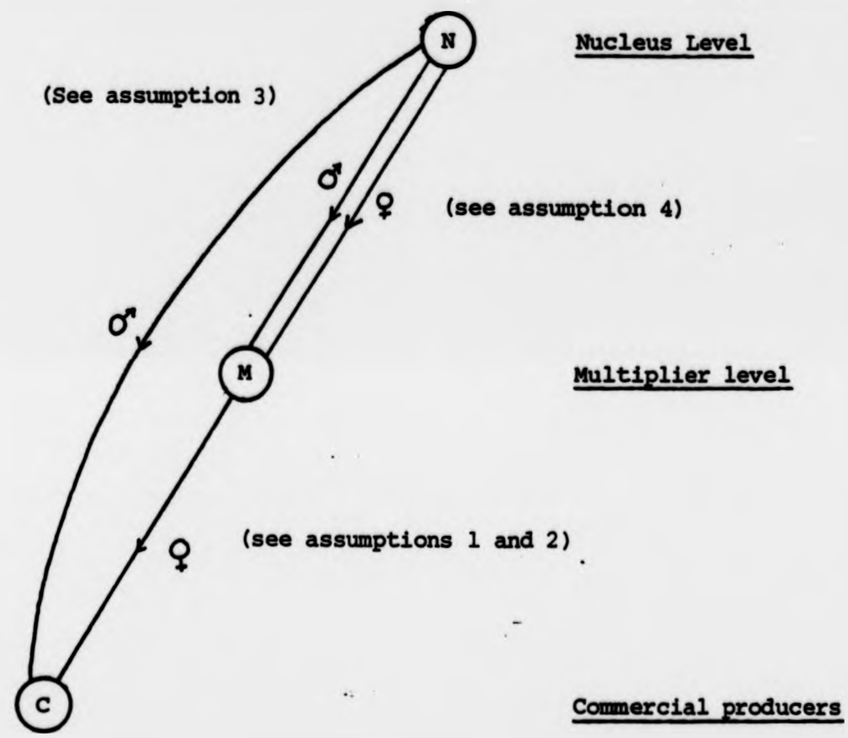
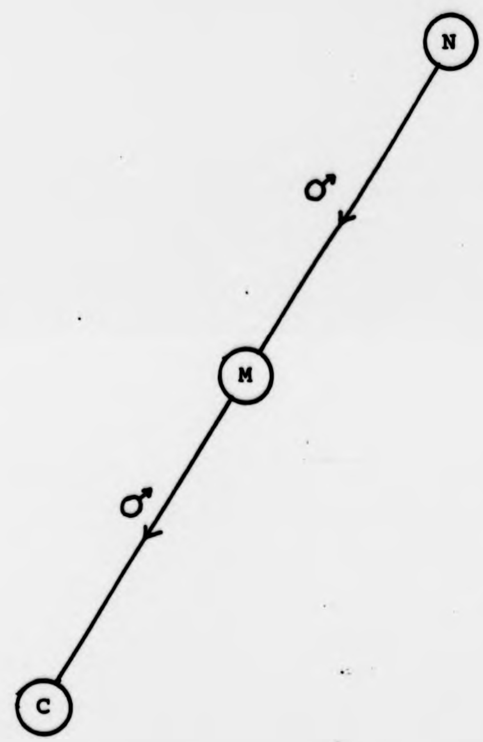


Figure 5.2 **The "Traditional" style Dissemination Pathway**



Nucleus

Multiplier

Commercial producers

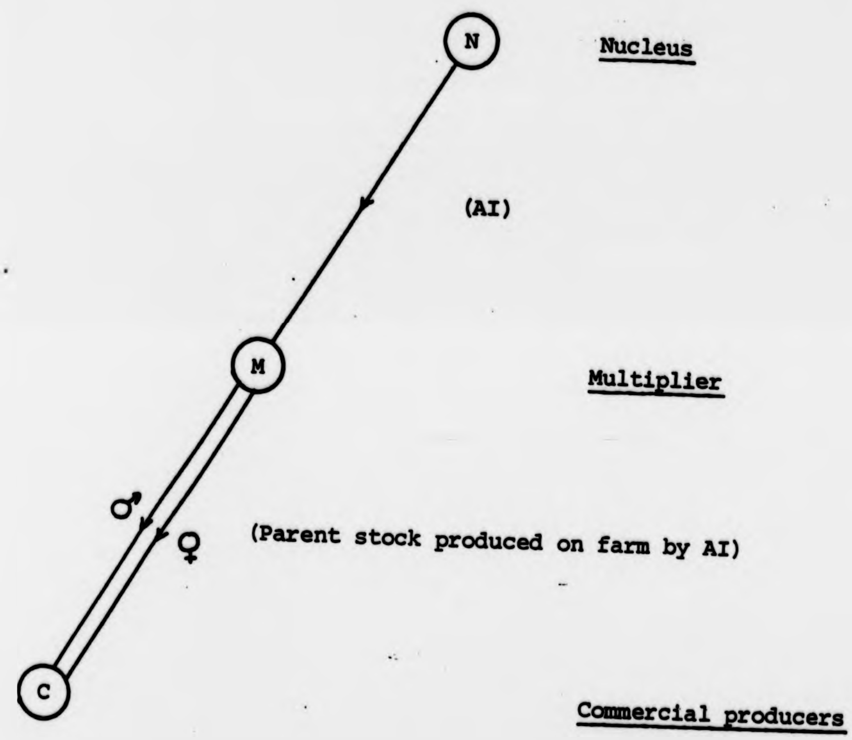
In addition to the dissemination paths described above, it is necessary to add a further path which Bichard does not consider relating to the use of artificial insemination (AI). H Reed (personal communication) has indicated that the majority of inseminations are used in the commercial herds to produce parent stock (to breed the slaughter animals). There are no records of what type of stock is produced from these inseminations so it is difficult to estimate the lag and impact of this path.

It is felt (D Steane and H Reed, personal communication) that the majority of inseminations are used to produce gilts. One of the major reasons for using AI is the health aspect (less chance of bringing disease into the herd). It would be reasonable to suppose, then, that the tendency would be for such farmers to produce their own boars too, to avoid bringing in any livestock. The assumption is therefore made:

8. All AI used to produce parent stock is used on the same farms to produce both boars and gilts. That is, a third pathway is assumed as illustrated in Figure 5.3.

With these assumptions, then, more than one idealised pathway or "pyramid" for dissemination is identified and each can be taken as if it worked separately. These pathways do not account for the entire pig industry, however. The MLC's experience is that the entire industry will be affected by "improved genes" at some time. An MLC trial (Trial 25) comparing improved stock with bought-in stock with no testing history in their parentage was stopped because of the difficulty in finding any such unimproved animals. There is, therefore, a remainder for which a lag must also be estimated.

Figure 5.3 The Artificial Insemination Dissemination Pathway



No attempt is made to try and keep separate the influences of the breeding companies and the nucleus herds to guage the impact of each. Further assumptions might be made which would not be accurate in describing how the industry works in practice, but would allow the estimation of overall benefits from the two sources. This distinction is not felt practical, however, because of the imperfect nature of the data, which means that pooling the figures is necessary to estimate the sales for earlier years (see Section 5.3). Some comments will be made concerning the relative impacts of the nucleus herds and breeding companies in Chapter 9.

5.1.2 Methods of estimating the numbers of breeding stock present in the Commercial Herds

The approach adopted is essentially to follow the use of stock sold to estimate the numbers of breeding stock present in the commercial herds from the different pathways identified. These estimates can then be compared with the total numbers of breeding stock in the commercial industry in each year to estimate the proportions of the industry following each pathway.

Let the sales of improved stock in year (t) be

w_t crossbred gilts

x_t purebred gilts

y_t boars

z_t the number of artificial inseminations producing crossbred gilts.

Then figures for sales of stock and inseminations from the improvement herds (nucleus, multiplier and breeding company) may be used as follows:

1. Crossbred Gilts

If sales take place evenly over the year, then the "average" sale is in mid-year. The crossbred gilts sold in year (t) will, then, on average be in the herd for half of that year and the two subsequent years (with a 2.5 year life in the herd). The numbers of crossbred gilts brought in in this way that are present in any year can then be traced out (Table 5.1). Thus the number of crossbred females from this source present in the herd in a given year (t) can be seen to be the sum of half the sales of crossbred gilts for that year and the sales in the previous two years. The total number of crossbred females present in the herd are thus estimated as:

$$\tfrac{1}{2}\, w_t + w_{t-1} + w_{t-2} \qquad (1)$$

2. Purebred Gilts

Again, following a typical gilt sold in the middle of the year, the first litter of that gilt will be produced at the end of that year (approximately) and the next three litters at six-monthly intervals after that. From each litter it is assumed two crossbred gilts will result (on average) to take their places in the breeding herd. These will reach "maturity" approximately six months after birth. Thus, if x_t purebreds are sold to the commercial herds, on average in the middle of year (t), $2x_t$ crossbred gilts from their first litters will enter the herd half-way through year (t+1) and will remain there for 2.5 years. Another $2x_t$ crossbred gilts will enter the herd at the end of year (t+1), another $2x_t$ in the middle of year (t+2) and the final $2x_t$ at the end of year (t+2) (Table 5.2a). Thus the total number of crossbred females in the commercial herd as a whole resulting from purebreds bought in year (t) can be calculated (Table 5.2b).

Table 5.1 <u>Presence of Crossbred Gilts in Commercial Herds</u>

From sales in year	Year			
	t	t+1	t+2	t+3
t	$\frac{1}{2}W_t$	W_t	W_t	
t+1		$\frac{1}{2}W_{t+1}$	W_{t+1}	W_{t+1}
t+2			$\frac{1}{2}W_{t+2}$	W_{t+2}
t+3				$\frac{1}{2}W_{t+3}$

Table 5.2a <u>Impact of Purebred Gilt Sales</u>

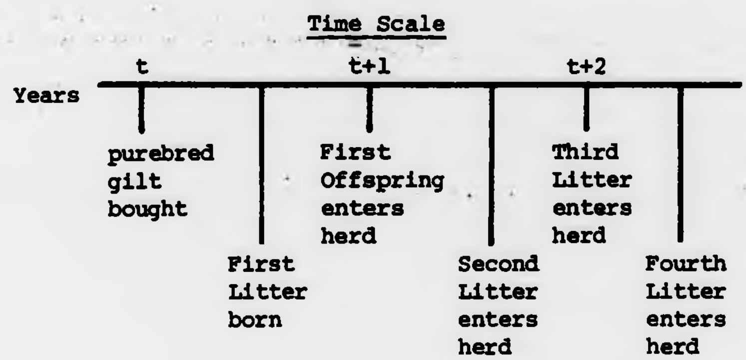


Table 5.2b <u>Crossbred Females present in the herd Resulting from the Sales of x_t Purebreds in year t</u>

Litter	Year					
	t	t+1	t+2	t+3	t+4	t+5
First		x_t*	$2x_t$	$2x_t$		
Second			$2x_t$	$2x_t$	x_t	
Third			x_t	$2x_t$	$2x_t$	
Fourth				$2x_t$	$2x_t$	x_t
	-	x_t	$5x_t$	$8x_t$	$5x_t$	x_t

* represents $2x_t$ present for half the year (on average).

The number of crossbred gilts present in the commercial herds for breeding slaughter animals in year (t), from this path, is then:

$$x_{t-1} + 5x_{t-2} + 8x_{t-3} + 5x_{t-4} + x_{t-5} \qquad (2)$$

Hence the numbers of crossbred females in the breeding herd in any year that have been brought in from improved sources or are the daughters of purebreds bought from improved sources can be calculated. These figures can be compared with the total numbers of sows in the breeding herds to give a proportion of the industry in a given year, following the "company" style pathway. This proportion can be applied to the total number of boars in the industry to discover the number of boars needed to service these females.

3. Boars

By reasoning as above and with a two year boar life in the herd, the average number of boars in the herd from improved sources in year (t) will be:

$$\tfrac{1}{2} y_t + y_{t-1} + \tfrac{1}{2} y_{t-2} \qquad (3)$$

Subtracting the number of boars needed to service the above sows from the number of improved boars in the herd, the number of boars left for the "Traditional" style of dissemination pathway is estimated. From this figure the proportion of the industry affected by this pathway can be estimated by comparing it with the total number of boars in the national herd in a particular year.

4. Artificial Inseminations

Taking the average insemination as being in mid-year, the average offspring of that insemination will be entering the herd as a replacement gilt approximately one quarter of the way through the following year and remaining in the herd for 2.5 years. Thus, the number of females in the herd in year (t) produced by artificial inseminations (assuming two gilts taken from each litter) will be:

$$1.5z_{t-1} + 2z_{t-2} + 1.5z_{t-3} \qquad (4)$$

5.1.3 The Data Used

Figures are necessary for:

1. The sales of breeding stock from the improvement herds (the nucleus, multiplier and independent breeding company herds).
2. The number of artificial inseminations used to produce crossbred gilts.
3. The numbers of sows and boars present in the commercial herds in each year.

1. The Sales of Breeding Stock

The sales figures for breeding stock are shown in Table 5.3. The missing figures are no longer available. With the limited number of years, and the variation evident in the figures, it is not possible to establish reliable trends which might be extrapolated. Taking the figures from 1972 to 1977 and applying them for the years 1965 to 1971 would overstate the influence of the scheme in the early years. Over the years there has been a movement from the "Traditional" style pathway to the "Company"

Table 5.3 Sales Figures for Breeding Stock

	Year	Nucl. & res. incl. (Central test)	Multipliers	Breeding Companies
Boars	1968	←	7,485	→
	1972	5,210	n.a.	5,428
	1973	n.a.	n.a.	n.a.
	1974	3,936	n.a.	6,738
	1975	4,000	379	9,629
	1976	4,804	285	8,987
	1977	5,172	137	7,326
Purebred Gilts	1972	8,644	n.a.	3,233
	1973	n.a.	n.a.	n.a.
	1974	6,512	n.a.	6,339
	1975	4,560	1,305	4,000
	1976	8,861	496	8,348
	1977	7,438	159	3,800
Crossbred Gilts	1972	4,802	n.a.	47,325
	1973	n.a.	n.a.	n.a.
	1974	2,593	n.a.	53,757
	1975	3,695	3,808	63,000
	1976	5,195	4,710	61,164
	1977	5,564	2,436	57,009

Source: D Steane, personal communication.

style (D Steane, personal communication). Also, the influence of nucleus multiplier herds has decreased over recent years. Current sales from the breeding companies, particularly of crossbred gilts, would also give an overestimate of sales for the earlier years.

The following procedures are adopted to obtain estimates of the sales of stock year by year to the commercial industry:

1. Adjustment is made to nucleus herd sales, as shown in Table 5.3, for stock sold to other nucleus, multiplier and company herds, as only sales to commercial herds are required.

2. All sales for nucleus, reserve nucleus, breeding company and multiplier herds are aggregated for the years 1972-77 (multiplier sales for 1972 and 1974 are taken as the average for years 1975-77). This is done as it is felt that extrapolating the total sales from all improved sources can be done with rather more confidence than for the individual sources.

3. Boar sales for the missing years are taken as growing evenly from 1967 to 1976, and from 1972 to 1974.

4. Crossbred gilt sales are taken as zero in 1968 and as having grown evenly to 1972, and from 1972 to 1974.

5. Purebred gilt sales are taken as even over the whole period, starting from 1967.

6. All figures are rounded to the nearest 100.

The resulting estimates are shown in Table 5.4.

Table 5.4 Estimated Sales to Commercial Herds

Year	Boars	Crossbred Gilts	Purebred Gilts
1967	5,800	4,000	11,500
1968	6,600*	14,300	11,500
1969	7,400	24,500	11,500
1970	8,400	34,700	11,500
1971	9,300	45,400	11,500
1972	10,300*	55,800*	11,100*
1973	10,400	57,800	11,500
1974	10,500*	60,000*	12,400*
1975	13,500*	70,500*	9,100*
1976	13,500*	76,100*	15,400*
1977	12,000*	65,000*	10,000*

* Based on actual sales figures for that year.

2. Contribution of Artificial Insemination

The numbers of AIs each year (H Reed, personal communication) are shown in Table 5.5. The numbers of inseminations used to produce crossbred gilts are estimated as follows:

1. Approximately 60% of inseminations are used in the commercial industry to produce parent stock (H Reed, personal communication).
2. An average farrowing rate is 75% (D Steane, personal communication).
3. About one-third of the inseminations are used to produce replacement purebred sows and purebred boars for mating with crossbred females.

Thus, if the number of inseminations in year (t) is z'_t, the number of inseminations producing crossbred gilts, z_t, will be:

$$z_t = 0.60 \times 0.75 \times 0.67 \, z'_t \qquad (5)$$

Hence the number of inseminations producing crossbred gilts are as in Table 5.6.

3. Numbers in Commercial Herds

The total number of sows and boars in the commercial herds year by year must also be estimated. Figures for the total number of sows and boars in Great Britain are available (T Fowler, personal communication) and are adjusted for sows and boars in the improvement herds. Current estimates of the numbers of breeding stock in improvement herds (D Steane, personal communication) are given in Table 5.7. The 3,000 boars in the improvement herds is subtracted from the total boar population for each year, to give the estimates in Table 5.8. In estimating the commercial sow population, the growth of the breeding companies and their multiplication systems would inflate this figure in the earlier years and adjustment is made accordingly.

Table 5.5 Numbers of Inseminations per Year

Year	Inseminations (000s)
1968	34
1969	42
1970	62
1971	76
1972	86
1973	91
1974	72
1975	59
1976	67
1977	62
1978	61

Source: H Reed (MLC)

Table 5.6 Numbers of Artificial Inseminations producing Crossbred Gilts (Estimated)

Year	Inseminations (000s)
1968	10.2
1969	12.6
1970	18.6
1971	22.8
1972	25.8
1973	27.3
1974	21.6
1975	17.7
1976	20.1
1977	18.6

Table 5.7 **Estimated Breeding Stock in Improvement Herds**

Sows:	Nucleus and reserve nucleus	7,000
	Breeding Companies	5,000
	Nucleus mating lines	2,000
	Company mating lines	40,000
		54,000
Boars:	Total	3,000

Table 5.8 **Estimate of Number of Sows and Boars in Commercial Herds for Slaughter Stock**

Year	Sows (000s)	Boars (000s)
1967	835	35
1968	835	36
1969	858	37
1970	881	37
1971	900	38
1972	878	38
1973	929	41
1974	841	37
1975	771	34
1976	848	37
1977	777	35

5.1.4 Estimation of the proportions of the commercial industry following each dissemination pathway

From above ((1) and (2)) the number of crossbred sows from improved sources is given by:

$$\tfrac{1}{2}w_t + w_{t-1} + w_{t-2} + x_{t-1} + 5x_{t-2} + 8x_{t-3} + 5x_{t-4} + x_{t-5}$$

and the number of boars (from (3) above) by:

$$\tfrac{1}{2}y_{t-1} + y_{t-2} + \tfrac{1}{2}y_{t-3}$$

Applying the sales figures estimated (Table 5.4) and relating the results to the estimates of industry size (Table 5.8), the proportions of the commercial industry estimated to be following the "Traditional" and "Company" style pathways (of Figures 5.1 and 5.2) in each of the years are shown in Table 5.9 (more detailed working is shown in Tables 5.10 and 5.11). The numbers of crossbred gilts produced by AI can be estimated from Table 5.6 and the proportion of the industry affected derived. Again the results are shown in Table 5.9 (with detailed workings in Table 5.12). The remaining proportions of the industry for different years are also given in Table 5.9.

Table 5.9 Proportions of the Commercial Industry estimated to be following the alternative dissemination paths (%)

Year	Company Style	Traditional	A.I.	Remainder
1968	2.7	22.6		
1969	11.6	24.1	1.8	62.5
1970	24.6	15.7	4.5	55.2
1971	33.4	10.7	7.6	48.3
1972	38.5	10.6	10.3	40.6
1973	38.7	10.4	12.1	38.8
1974	44.2	12.0	15.1	28.7
1975	49.4	16.6	16.3	17.7
1976	47.0	21.9	11.8	19.3
1977	53.1	21.9	12.6	12.4

Table 5.10 <u>Presence of sows in the herd (thousands)</u>

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Crossbred gilts resulting from purebred gilt sales	* year of purchase	x 1	x 5	x 8	x 5	x 1					
		11.5	57.5 11.5	92.0 57.5 11.5	57.5 92.0 57.5 11.5	11.5 57.5 92.0 57.5 11.5	11.5 57.7 92.0 57.5 11.1	11.5 57.5 92.0 55.5 11.5	11.5 57.5 88.8 57.5 12.4	11.5 55.5 92.0 62.0 9.1	11.1 57.5 99.2 45.5 15.4
Purchased crossbred gilts	x ½ year of purchase	x 1	x 1								
	2	4 7.2	4 14.3 12.3	14.3 24.5 17.4	24.5 34.7 22.7	34.7 45.4 27.9	45.4 55.8 28.9	55.8 57.8 30.0	57.8 60.0 35.3	60.0 70.5 38.1	70.5 76.1 37.5
TOTAL	2	22.7	99.6	217.2	300.4	338.0	359.7	371.6	380.8	398.7	412.8

Table 5.11 Presence of boars in the herd (thousands)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
	x ½	x 1	x ½								
Boars purchased	2.9	5.8	2.9								
from		3.3	6.6	3.3							
improved			3.7	7.4	3.7						
sources				4.2	8.4	4.2					
					4.7	9.3	4.7				
						5.2	10.3	5.2			
							5.2	10.4	5.2		
								5.2	10.5	5.2	
									6.8	13.5	6.8
										6.8	13.5
											6.0
TOTAL	2.9	9.1	13.2	14.9	16.8	18.7	20.2	20.8	22.5	25.5	26.3

Table 5.12 Presence of sows bred by AI in Commercial Herds (thousands)

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
	x 1.5	x 2	x 1.5								
Crossbred gilts produced by AI (see text for assumptions)			15.3	20.4 18.9	15.3 25.2 27.9	18.9 37.2 34.2	27.9 45.6 38.7	34.2 51.6 41.0	38.7 54.6 32.4	41.0 43.2 26.5	32.4 35.4 30.2
Total			15.3	39.3	68.4	90.3	112.2	126.8	125.7	99.7	97.8

5.2 GENETIC LAGS

Bichard (1971) examines the way in which additive genetic improvement made in a nucleus population is passed to successive levels in a multiplication system. A brief description of his simplest calculation illustrates how lower levels in a multiplication system lag behind the nucleus level and how these lags may be expressed as a function of time. Bichard starts with a simple two tier system in which the nucleus supplies a multiplier level with males, the multiplier level keeping their own replacement females. The males are average representatives of the nucleus output at any time. Males are replaced from the same source after one year and females are replaced by average daughters after one year. Let ΔG be the annual rate of improvement in the nucleus level, N_y the average merit of the progeny born in the nucleus in year (y), and M_y the merit of progeny born in the multiplier level. If $M_o = D$, then:

$$M_1 = \tfrac{1}{2}(M_o + N_o) = \tfrac{1}{2}D \qquad (6)$$

$$M_2 = \tfrac{1}{2}(M_1 + N_1) = \tfrac{1}{4}D + \tfrac{1}{2}\Delta G \qquad (7)$$

and in general the following relationship can be determined:

$$M_y = (\tfrac{1}{2})^y D + (y-2 + (\tfrac{1}{2})^{y-1})\Delta G \qquad (8)$$

or as y increases:

$$M_y \approx (y-2)\Delta G \qquad (9)$$

Thus the improvement accumulates in the two levels at the same rate but the multiplier level lags behind by two years. Bichard goes on to consider more complex systems involving three levels, stock of different merits being used in the lower levels, home bred males being used in the lower levels, overlapping generations and the transfer of females. Formulae are derived for calculating the average lag in years for these different multiplier structures and it is these formulae that are used below. Finally Bichard discusses the scope for reducing improvement lags within the context of livestock production in Britain.

For the purposes of the current study three factors are relevant in estimating the average lags for the different dissemination pathways in the pig industry:

1. The method by which the improvement is passed on (the appropriate dissemination pathway). Obviously a dissemination such as the "Company" style will have less lag than the "Traditional" style since males and females are being passed down in the former and only males in the latter.

2. The length of time breeding stock are used. A herd with an average replacement time of 2.5 years will lag behind a herd with an average of 1.5 years.

3. The degree of selection practiced. The higher the merit of the stock passed down the "pyramid", the shorter the lag.

The selection practiced is considered first and then the average lags for each of the pathways described above are calculated. Finally some adjustments are made to the lags for the early years.

1. <u>Selection of Parent Stock</u>

The average pig in nucleus herds is set each year at 100 index points, with a standard deviation of 35 points. All boars scoring less than 90 points in the test are culled. Thus the average score of boars surviving the test is about 120 points. Of these, the very best will be used for artificial insemination. These will all have scored at least 150 points, with an average of about 170 points. Of the others, the better boars will tend to be used to sire parent stock and the poorer boars to sire slaughter stock. Averages are taken as about 140 points and 110 points respectively. Taking the value of a boar index point as 2.29p (G L Cook, 1977), the additional value of an AI boar compared with an average nucleus boar is:

(170 - 100) x 2.29 = 160.3p

For sires to breed parent stock and slaughter stock the respective values are 91.6p and 22.9p. With genetic progress valued at 67.5p per pig per year (valuing the progress estimates of Chapter 4 with the same economic values used by G L Cook, 1977) the additional benefits over an average nucleus sire are the equivalent of 2.37 (160/67.5), 1.36 and 0.34 years respectively.

2. <u>The lags related to different pathways</u>

a. The "Traditional" Style Pathway:

The calculation of the lag for this dissemination pathway is given by Bichard (1971) in his equation 10a:

$$C_y = (y - \tfrac{1}{4}(l_m + l_f + l'_m + l'_f - 4) - (a_m + a_f + a'_m + a'_f))\Delta G \qquad (10)$$

where ΔG is the genetic progress per year in the nucleus level,

C_y is the improvement in the commercial herd in year y over year 0,

a_m and a_f are the ages of the males and females when their first progeny are born in the herd,

l_m and l_f are the numbers of half yearly intervals males and females are in the breeding herd,

a'_m, l'_m, etc. relate to the second tier of the pathway or 'pyramid'.

In the present case:

$$C_y = (y - \tfrac{1}{4}(4+4+4+5-4) - (1+1+1+1))\Delta G$$
$$= (y - 7.25)\Delta G$$

The average lag produced is 7.25 years. That is the commercial herds in this pathway lag, on average, 7.25 years behind the nucleus herds.

This takes no account of the degree of selection of parents. Since the boars breeding the parent stock are selected, 1.36 years can be deducted from this lag, leaving a lag of 5.89 years. If the progress in the nucleus is Xp per pig per year, then with no selection of stock to be sold from the nucleus, the one year's progress for the nucleus would be seen in the commercial herd 7.25 years later. Since the pigs sold are 1.36 times better than average, however, after 7.25 years, the pigs in the commercial herd will be 2.36Xp better than in year 0.

b. The "Company" Style Pathway:

The lag for this pathway is calculated using Bichard's equation 12:

$$C_y = (y - \frac{1}{16}(l_m + l_f - 2) - \tfrac{1}{8}(l'_m + l'_f - 2) - \tfrac{1}{4}(a_m + a_f) - \tfrac{1}{2}(a'_m + a'_f))$$

$$\Delta G + \tfrac{1}{4}(\Delta G'_m + \Delta G'_f) + \tfrac{1}{2}(\Delta G''_m + G_{f'}) \qquad (11)$$

where males and females used in the multipliers differ from average merit by $\Delta G'_m$ and G_f and males and females in the final tier by $\Delta G''_m$ and $G_{f'}$, so that the final two terms take account of the superiority of boars.

The lag is given, therefore, by:

$$C_y = (y - \frac{1}{16}(4+4+2) - \tfrac{1}{8}(4+5-2) - \tfrac{1}{4}(1+1) - \tfrac{1}{2}(1+1))\Delta G$$

$$+ \tfrac{1}{4}\ (1.36\Delta G + 0) + \tfrac{1}{2}(0.34\Delta G + 0)$$

$$= (y - 2.75)\Delta G + 0.51\Delta G$$

$$= (y - 2.24)\Delta G$$

Thus with no selection the lag is 2.75 years, and, with the selection described above, this reduces to 2.24 years.

c. Artificial Insemination:

Bichard did not consider the pathway described above for AI. However the lag can be derived by combining two of his equations. The first term from equation 9a (the lag between the multiplier and the nucleus in the "Traditional" pathway) and the second from equation 12:

$$C_y = (y - \tfrac{1}{4}(l_m + l_f - 2) + \tfrac{1}{2}(a'_m + a'_f))\Delta G$$

$$- (\tfrac{1}{8}(l'_m + l'_f - 2) + \tfrac{1}{2}(a'_m + a'_f))\Delta G \qquad (12)$$

Thus the lag is given by:

$$C_y = (y - \tfrac{1}{4}(4+4-2) - (1+1) - \tfrac{1}{8}(4+5+2) - \tfrac{1}{2}(1+1))\Delta G$$

$$= (y - 5.38)\Delta G$$

Taking account of the superiority of boars used for AI a further 2.37 years can be deducted from this lag to yield a final estimate of 3.01 years.

d. The Remainder of the Commercial Industry:

Since it is assumed the entire industry is affected eventually, some estimate is required of the average lag for the remainder of the industry not accounted for above. Without an understanding of where this section of the industry obtains its improved stock a good estimate of this lag is not possible. It is reasonable to suppose that the lag must be longer than any of the above pathways. An arbitrary lag of 10 years has been chosen. Further consideration will be given to its value in Chapter 8.

3. <u>The Genetic Lag in the Early Years</u>

A problem with these estimates of lags is that they are averages which apply when the pathways have settled down and are in equilibrium. When the system is well established, the lag will be steady for a particular pathway. At the scheme's inception, however, there will be a zero lag between the nucleus and commercial herds. In the next few years the commercial herds will get some improvements before the period of the average lag has expired. The lag will begin as zero and increase gradually until an equilibrium is reached.

To estimate the lags in these early years it is necessary to follow through the movement of stock in detail for each pathway. This is done for the "Traditional" and "Company" style, and AI pathways. The "Company" style pathway's calculation is given in Table 5.13 as an illustration.

Table 5.13 **Calculation of Lag for Company Style Pathway**

Columns

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Nucleus Herd	Sows and Boars in Multiplier (months)					Crossbred Sows in Commercial Herds						Slaughter Stock	Revised Slaughter Stock
	0-6	6-12	12-18	18-24	24-30								
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1†	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0	0	0	0	0	0
3	2	1	0	0	0	0	0	0	0	0	0	0	.13
4	3	2	1	0	0	.25	0	0	0	0	0	.13	.38
5	4	3	2	1	0	.75	.25	0	0	0	0	.38	.78
6	5	4	3	2	1	1.5	.75	.25	0	0	0	.78	1.35
7	6	5	4	3	2	2.5	1.5	.75	.25	0	0	1.35	2
8	7	6	5	4	3	3.5	2.5	1.5	.75	.25	0	2	2.75
9	8	7	6	5	4	4.5	3.5	2.5	1.5	.75	.25	2.75	3.6
10	9	8	7	6	5	5.5	4.5	3.5	2.5	1.5	.75	3.6	4.53
11	10	9	8	7	6	6.5	5.5	4.5	3.5	2.5	1.5	4.53	5.5
12	11	10	9	8	7	7.5	6.5	5.5	4.5	3.5	2.5	5.5	6.5
13	12	11	10	9	8	8.5	7.5	6.5	5.5	4.5	3.5	6.5	7.5
14	13	12	11	10	9	9.5	8.5	7.5	6.5	5.5	4.5	7.5	8.5
15	14	13	12	11	10	10.5	9.5	8.5	7.5	6.5	5.5	8.5	9.5‡

† Half yearly intervals

‡ When average merit of nucleus herd is 15, the average merit in the commercial herd is 9.5, so the lag is 5.5 periods or 2.75 years.

Working in half yearly periods, let the average merit of stock produced in the nucleus herd be progressing by one unit per period (Column 1). The genetic merit of the males and females entering the multiplier level from the nucleus each period is then shown in Column 2. This stock will then produce its first offspring in the next period and will remain in the multiplier herd for four periods. Columns 3 to 6 show the merits of breeding animals of different ages present in the herd in any one period. Assuming a constant population size, the cross-bred gilts coming out of the multiplier levels therefore have a quality equal to the average of Columns 3 to 6. That is, the crossbred females going into the commercial herds have an average merit as shown in Column 7. The presence of these pigs in the commercial herds can then be traced through Columns 8 to 12, and the average merit of sows in the commercial herds in any period calculated. Combining this with the average quality of the boars they will be mated with (Columns 3 to 6) the average quality of slaughter stock each period is worked out (Column 13). The pathway can be seen to have reached equilibrium when the commercial herds are progressing at the same rate each period as the nucleus. It should be noted that this working implies all transfers of stock from one stage to the next take place at the end of the six monthly periods. This simplification has the effect of adding a further six months to the lag, hence improvements shown in Column 13 would, in fact, be achieved six months earlier, as in Column 14.

The quality of stock produced by nucleus and commercial herds can be compared each year to find the lag for that year. For each pathway the average lag each year is calculated as above.

Approximate adjustments are made for the relative qualities of boars used for different purposes. The results, rounded to one decimal place, are as shown in Table 5.14. The lags for the remainder of the industry are taken as shown.

Table 5.14 Length of lag for Different Dissemination Pathways in Early Years

Years since Start of Scheme	Lags (in Years)			
	Company Style Pathway	Traditional Style	A.I.	Remainder
0	0	0	0	0
1	1.0	1.0	1.0	1.0
2	1.8	2.0	2.0	2.0
3	2.1	2.8	2.7	3.0
4	2.2	3.4	2.6	3.9
5	2.2	3.4	1.8	4.8
6	2.2	3.7	2.1	5.7
7	2.2	4.2	2.4	6.5
8	2.2	4.6	2.6	7.3
9	2.2	4.9	2.7	8.1
10	2.2	5.1	2.8	8.6
11	2.2	5.3	2.9	9.0
12	2.2	5.5	2.9	9.3
13	2.2	5.6	3.0	9.6
14	2.2	5.7	3.0	9.8
15	2.2	5.7	3.0	9.9
16	2.2	5.8	3.0	10.0
17	2.2	5.8	3.0	10.0
18	2.2	5.9	3.0	10.0

5.3 THE BENEFITS OF PIG IMPROVEMENT AT THE COMMERCIAL FARM LEVEL

The proportions of the commercial industry's breeding stock having come from each of the dissemination pathways has been calculated in Section 5.1. These are used as estimates of the proportions of the commercial industry following each of the dissemination pathways. These proportions are applied to the numbers of animals slaughtered in the following year and combined with the estimates of the genetic lags involved, from Section 5.2, to estimate the benefits year by year from the different pathways in terms of expressions of the improvement per pig per year achieved in the improvement herds.

The numbers of pigs slaughtered per year are as shown in Table 5.15 (T Fowler, personal communication). Only genetic improvement achieved by the improvement herds before 1978 is considered. Even if no further investment in testing were made, however, there would still be improvements to reach the commercial herds because of the lags involved. Further, since the whole pig population is being affected, the genetic change brought about since 1966 will not be lost in future generations. Thus to only count benefits achieved up to 1977 will clearly underestimate total benefits. At the other extreme benefits could be considered in perpetuity. This proposition is dismissed on two accounts, however:

1. Uncertainty as to the future size of the pig industry. Possible changes in taste, income, feed costs and other factors make any predictions about the future very difficult.

Table 5.15 Total Pig Slaughtering in Great Britain (excluding sows and boars) in Thousands

1968	11,082	(estimated)
1969	12,046	
1970	12,267	
1971	13,529	
1972	13,334	
1973	13,192	
1974	13,425	
1975	11,635	
1976	12,184	
1977	12,814	
1978	12,408	

Source: T Fowler, MLC

2. Uncertainty as to possible future changes in the requirements of the industry. So far selection has produced changes in a particular direction for each of a number of traits. While such genetic changes will be permanent, the value of that change may not. Changes in taste, for example, may mean that the requirements of the industry in the future may be different from those of today.

In the first instance future benefits are evaluated only within some period for which prediction can be made with some confidence (though this restriction will be modified later, in Chapter 8). Obviously such a choice of period is arbitrary. Estimates of future pork and bacon production for 1979, 1982 and 1985 were given by R J Bansback (1978) and it has been decided to count benefits up to 1985 based on these estimates. Intermediate years are estimated by extrapolation. The percentage increases over current levels are applied to actual recent slaughter figures to obtain estimates of future slaughterings per year (Table 5.16). The proportions of the industry affected by the different lags in 1977 are used for estimating benefits in the later years.

If the annual rate of progress in the improvement herds is ΔG per pig, then the benefits are estimated as shown in Table 5.17.

Table 5.16 Forecast Pig Slaughterings to 1985

(Excluding Sows and Boars) in Thousands.

1979	13,077	(estimated)
1980	13,100	(forecast)
1981	13,200	"
1982	13,200	"
1983	13,500	"
1984	13,800	"
1985	14,200	"

Source: Based on estimates of pork and bacon production for 1979, 1982 and 1985, R J Bansback (1979).

Table 5.17 **Benefits achieved per year in the Commercial Industry**

(in Thousands ΔG)

Year	Company Style	Traditional	Artificial Insemination	Remainder	Total
1968	60				60
1969	1,258	581	65		1,904
1970	5,432	1,156	773	677	8,038
1971	12,652	2,316	3,290	1,307	19,565
1972	19,508	3,251	5,356	1,624	29,739
1973	24,505	3,842	7,343	2,559	38,249
1974	34,416	5,477	10,947	2,697	53,537
1975	39,084	7,919	11,948	1,853	60,804
1976	44,667	13,075	10,352	3,292	71,386
1977	59,877	15,996	13,078	3,178	92,129
1978	64,569	17,663	14,227	4,154	100,613
1979	74,994	21,193	16,477	5,513	118,177
1980	76,517	23,812	18,157	6,822	125,308
1981	77,101	26,884	18,295	8,348	130,628
1982	77,101	29,486	18,295	9,821	134,703
1983	78,854	32,522	18,711	11,718	141,805
1984	80,606	33,244	19,127	13,690	146,667
1985	82,942	34,208	19,681	15,847	152,678

Chapter 6

THE VALUE OF THE GENETIC IMPROVEMENT IN PIGS

Estimates of the genetic improvement achieved in the herds carrying out selection have been given in Chapter 4 and the process through which improvement is disseminated to the commercial herds has been considered in Chapter 5. The purpose of the current chapter is to attempt to value the improvement achieved at the commercial level in financial terms. This is done by estimating an aggregate value of one year's improvement over all of the individual traits examined in Chapter 4. This figure can then be combined with figures from Chapter 5 to estimate total benefits achieved by the pig industry.

The MLC have derived economic values per unit progress in each of the six traits concerned. These are used, along with genetic information on heritability and correlations, for weighting in the boar selection index. These economic values are taken as a starting point below. The traits are examined individually at first. Consideration is given to the accuracy of the monetary values used by the MLC and of the workings involved. The values are then related to the estimates of improvement in each trait from Chapter 4. For simplicity constant prices will be used, with 1977 price levels as a base. It is assumed that inflation will have affected costs and benefits equally over the period. The comparative values of the different benefits are thought to have remained roughly constant over time (D Jones, MLC, personal communication) though some consideration will be given to this factor in the sensitivity analysis (Chapter 8).

After the traits have been considered individually they are aggregated into a figure for progress per pig per year which is used to estimate the total benefits realised by the industry. Finally a brief consideration of the concepts of consumer and producer surpluses is given and the method adopted for valuing genetic improvement in pigs is examined in relation to these concepts.

6.1 INDIVIDUAL TRAITS

1. Feed Conversion Ratio

In the MLC 1976 Pig Selection Indices Revision (G L Cook, 1977) the value of change in feed conversion ratio is explained as follows: "an increase of 0.1 in feed conversion would increase the consumption of feed by 7.2 kgs if pigs are fed over a weight range of 72 kgs. At a feed cost of approximately £75 per tonne, this would cost an extra 54p. A unit increase in feed conversion has therefore been valued at -540p." The figure for feed cost was increased to £120 per tonne in mid-1977, giving a value of -864p per unit increase (Cook, personal communication). Reference to Burnside, Sheppard and Thomas (1978), Nix (1978) and Pig Facts (MLC 1979) indicates the figure of £120 per tonne to be a realistic one for 1977.

It is assumed that with a better feed conversion ratio pigs will still be raised to the same average weight. A reduction in feed conversion ratio will then simply mean that for the same weight of pig, less feed is required. If progress is linear in terms of points in the ratio (as measured above, Chapter 4) then savings on feed are linear too, since the same quantity of feed is saved per pig by reducing feed conversion ratio from 3.1 to 3.0 as from 3.0 to 2.9. It is also assumed that the changes brought about by improving this trait will be insufficient to alter prices significantly in the feed market. Thus progress in this trait, per pig, may be valued as the progress made multiplied by the price of the feed per tonne (as in the MLC argument). With feed costs of £120 per tonne and estimated annual improvement of 0.0269 points in the feed conversion ratio (Table 4.1 above), this is equivalent to 23.2p per pig per year.

2. Daily Gain

The MLC evaluation for this trait (Cook, 1977) is: "animals produced normally are reared over a weight range of approximately 72 kgs in 140 days, representing a growth rate of 0.52 kgs per day. If growth rate were improved by 0.1 kgs per day animals would reach slaughter weight 24 days earlier. If we assume labour and overhead costs to be £5 per pig, this saving in time would be worth 86p per pig. The value of daily gain has therefore been set at 860p per kg." This 860p figure was increased to 953p in mid-1977 (Cook, personal communication).

The figure for labour and overhead costs is estimated as the sum of labour costs, depreciation on buildings and interest on working capital. The relevance of the latter two might be questioned. Benefits are seen in resources saved. Thus charges for buildings may not be relevant if they have already been incurred and cannot be avoided, so that real savings do not exist. It has been noted in Chapter 3, however, that the industry has been far from static and many farms have been expanding significantly so that there has been scope for real savings. In order to take the most conservative approach possible, however, this element of the MLC's figure will be omitted at first, though its possible impact will be considered later (in Chapter 8). Interest on working capital is calculated on the value of a weaner, plus the value of feed used to grow the pig over the period until slaughter, at a 13% interest rate (Jones, personal communication). Thirteen percent is taken to be representative of market rates of interest facing farmers in recent years. Whether particular farmers have borrowed to finance their operations is irrelevant here. The actual monetary sums paid by farmers to banks or other institutions as interest may be dismissed as transfer payments when looking from society's point of view. What is of importance is the opportunity cost of the capital employed. Because of the method of calculating total benefits employed the normal discounting procedure to bring benefits occurring in different years to a common basis (Chapter 8) will not be sufficient to take account of this. An element representing the opportunity cost will be included therefore in the value of daily gain. A 13% rate of interest may be seen as the product of inflation and market imperfections (Chapter 2). In real terms a more appropriate rate might be 5% (HMSO, 1978). Other costs not included in the MLC calculations might also be included in the value of daily gain. From Pig Facts (MLC, 1979) avoidable costs per pig may be taken as shown in Table 6.1.

Table 6.1 **Estimates of Avoidable Costs per Pig** (excluding feed)

Labour	£ 1.82
Farm transport	0.28
Veterinary and medical	0.07
Power and water	0.21
Miscellaneous expenses	0.29
Litter	0.21
Maintenance	0.22
TOTAL	£ 3.10

Source: Pig Facts (MLC, 1979).
Figures for Bacon pigs.

To these can be added an estimate of the opportunity cost of the working capital of £0.53 (at 5% interest), making the total £3.63 per pig. Using the MLC's method of calculation this gives a value for daily gain of £6.22 per kg.

The value of an increase in daily gain is seen in being able to get pigs to a given weight more quickly so reducing average labour and other costs. As with feed conversion ratio it is assumed that the weight at which pigs will be slaughtered remains the same. For the change to be of value depends on the further assumption that the extra capacity released by growing pigs faster is utilised for something else. Given this assumption the benefit can be expressed as a reduction in the number of days it takes a pig to reach slaughter weight. If pigs are raised over a 72 kgs weight range in 140 days, average daily gain is approximately 0.52 kgs per day. If growth rate is then improved by 0.1 kgs per day, animals would reach slaughter weight 24 days earlier (so the MLC agreement proceeds). However, with average daily gain at 0.62 kgs per day a further progress of 0.1 kgs per day would only save 16 days, and after that 12 days. Thus the level at which progress is made affects its value. Estimated progress per year is only 0.00491 kgs per day (see Table 4.1). Therefore the first year's progress in daily gain at the level used in MLC calculations may be calculated, if working with greater precision, to give a saving of 1.3 days. The accummulative benefit for subsequent years' progress as the average level of performance changes has been calculated and is given in Table 6.2.

Table 6.2 Value of Progress in Daily Gain

Year of Progress	No. of days saved per pig	Value per pig (p)
1	1.3	3.4
2	1.3	3.4
3	1.3	3.4
4	1.3	3.4
5	1.2	3.1
6	1.2	3.1
7	1.2	3.1
8	1.1	2.9
9	1.1	2.9
10	1.1	2.9

With total labour and other costs per pig of £3.63 per pig, it can be seen that the value of progress over ten years of selection falls from 3.4p to 2.9p per year. These changes could be incorporated into the estimation of benefits but for simplicity the average value of 3.2p per pig every year will be used.

3. Eye Muscle Area

The MLC evaluation states: "the value to the industry of increasing eye muscle area, over that associated with increased leanness, is difficult to quantify. Nevertheless, it is felt to have some value and has therefore been given a value of 3p per square centimetre".

The value of eye muscle area is, as stated, difficult to quantify. Given the lack of an objective measure of its value, approaching this problem afresh it might be considered wisest to err on the conservative side and omit selection for this trait altogether. (Some consideration will be given to it in the sensitivity analysis in Chapter 8).

4. Killing Out Percentage

While with feed conversion ratio and daily gain improvement can be simply expressed as savings per pig produced, improvement in killing out percentage (and the other traits below) effectively leads to a greater weight of carcass from each pig. To value this progress per pig it might be argued as follows. Let the costs associated with producing a pig be C, the original cost per kg c_1, the old weight per carcass A kgs, and the increased weight $(A + \Delta A)$ kgs. Then:

The old cost/kg (C_1) $= \frac{C}{A}$ (1)

and the new cost/kg $= \frac{C}{A+\Delta A}$ (2)

The reduction in cost of producing one kg is thus:

$$\frac{\Delta AC}{A(A+a)}$$

However, $C = Ac_1$ (from (1))

Therefore the saving per kg $= \frac{\Delta Ac_1}{(A+\Delta A)}$

The benefit per pig slaughtered is thus simply ΔAc_1, or the extra carcass weight valued at the original cost per kg and this indeed is how the MLC have valued improvement in the trait.

The MLC's argument for killing out percentage (Cook, 1977) is: "an average carcass of 62 kgs weight was worth approximately £43 when the index was calculated, that is 69.4p per kg. An increase of one percentage unit in killing out percentage would produce an extra 0.8 kgs carcass which would be worth 63p."

Reference to Burnside et al (1978) confirms this value per kg as being an accurate figure (paid by the wholesalers to the farmer).

Killing out percentage is expressed as a percentage of liveweight. Thus with improvement in this trait a given liveweight of pig will yield a greater weight of carcass. With a pig of liveweight 90 kgs an extra 1% of killing out percentage would yield an additional 0.9 kgs of carcass. This would be so irrespective of the original killing out percentage. The estimated progress of 0.109% per year (see Table 4.1) therefore yields an additional 0.098 kgs per pig per year on a pig of 90 kgs liveweight. A straight-forward application of the MLC's method of evaluation would therefore value this improvement at 6.8p per pig per year (valuing the carcass at 69.4p/kg). The actual value of a carcass is also dependant on trimming percentage however.

5. Trimming Percentage

The MLC evaluation is simply: "an increase of one unit in trimming percentage would produce an extra 0.6 kgs of carcass. At 69.4p per kg, this would be worth 43p."

Trimming percentage is expressed as a percentage of "killed out" weight. Thus the actual benefit from improving killing out percentage will depend on the absolute value of trimming percentage. For example, if trimming percentage were only 50% then if improvement in killing out percentage yielded an extra 1 kg of carcass, only 0.5 kg of that would be left after trimming. In the MLC's weighting, trimming out percentage is implied as being 80.6% (50 kgs left after trimming as a percentage of 62 kgs after killing out). Hence of the 0.098 kgs per pig per year progress calculated from improving killing out percentage only 0.079 kgs may be obtained after trimming.

Progress in trimming percentage itself may be seen as similar to killing out percentage so that the 0.082% progress per pig per year from the control comparisons (Table 4.1) yields 0.051 kgs extra carcass per pig per year. The additional carcass from compounding progress in both of these traits (ie 0.082% of 0.098 kgs) can be seen to be negligible, even after ten years of selection.

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Progress in killing out percentage and trimming percentage together can thus be seen as yielding an extra 0.13 kgs per pig per year of carcass at the trimmed stage. To produce this extra 0.13 kgs before the progress was made would have required a killed out carcass weighing approximately an extra 0.16 kgs (of significance since the economic value taken above is at that stage). Thus combined progress in these two traits can be valued at 11.1p per pig per year.

6. Lean percentage

The MLC evaluation for lean percentage is: "the two trimmed sides weigh approximately 25 kgs each. An extra one unit in percentage lean would provide an extra 0.5 kgs of lean largely at the expense of fat. If lean is worth 110p per kg more than fat, this would increase the value of the carcass by 55p."

The evaluation of the value of progress in percentage lean in side has been the subject of some detailed investigations in the meat trade by the MLC recently. The results confirm the above monetary value as a good estimate of the difference in value between lean and fat (J Chadwick, personal communication). It appears reasonable to assume that the loss of fat is not sufficient to appreciably alter the value placed on fat.

Lean percentage is calculated as the weight of lean in a side of pork as a percentage of the total weight in the side. Thus a 1% increase in lean percentage yields the same extra lean irrespective of the overall lean percentage before the improvement. With an average carcass consisting of two sides of approximately 25 kgs each, the estimated annual progress of

0.683% thus yields an additional 0.342 kgs of lean per pig. This may be valued as 37.6p (at 110p per kg). Again the additional benefit of a higher lean percentage on the slightly heavier carcass given by improvement in the other traits is negligible over the ranges dealt with.

6.2 THE TOTAL BENEFITS OF GENETIC IMPROVEMENT IN PIGS

Having considered all the traits individually in terms of reductions in cost per pig these can be added to estimate total benefits per pig per year. This assumes of course that such an addition across different traits is appropriate. There are two points which may be relevant here:

1. <u>The different stages at which benefits occur</u>

Feed conversion and daily gain are traits which manifest themselves at the farm level (a given weight of animal is produced for a lower input cost). The other traits are valued at later stages in the farmer/consumer chain. At each stage the total value of the carcass increases. Improvement has been valued at the stage at which it becomes evident. Aggregating the benefits achieved at different stages is consistent with an assumption that the value added at each stage is independent of the price before that stage (ie, wholesale margins are determined independently of the cost of the carcass rather than as a function of it). Ferris et al (1971) argue that such an assumption appears to be valid.

2. The independence of traits

Consideration of the traits would lead to the conclusion that whether or not progress in the six traits is related the value of such progress is independent. That is, even though a faster growth rate may help to produce better feed conversion figures for animals, the saving from reduced feed costs is additional to that from producing pigs faster. This is so for all the traits considered.

Accepting these arguments the progress in each of the traits added together gives an estimate of progress per pig per year of 75p (to the nearest whole penny). It may be noted that in straight-forward application of the MLC's weights (as used in Chapter 4 in considering CPE results) would yield very similar figures for each trait with an aggregate value of 76.7p per pig per year. Thus the conclusions drawn in Chapter 4 regarding the comparative improvements in company herds and central test nucleus herds, and in Chapter 5 in considering improvement lags, are unaltered. Combining this 75p figure with the estimates of the improvement evident in pigs slaughtered at the commercial level (from Table 5.17 above) total benefits year by year may be estimated as shown in Table 6.3. These benefits will be discounted and compared with costs in Chapter 8.

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Table 6.3 **Benefits Per Year** (£000s)

Year	Company Style	Traditional	Artificial Insemination	Remainder	Total
1968	45				45
1969	944	436	49		1,429
1970	4,074	867	580	508	6,029
1971	9,489	1,737	2,468	980	14,674
1972	14,631	2,438	4,017	1,218	22,304
1973	18,379	2,882	5,507	1,919	28,687
1974	25,812	4,108	8,210	2,023	40,153
1975	29,313	5,939	8,939	1,390	45,603
1976	33,500	9,806	7,764	2,469	53,539
1977	44,908	11,997	9,809	2,384	69,098
1978	48,427	13,247	10,670	3,116	75,460
1979	56,246	15,895	12,358	4,135	88,634
1980	57,388	17,859	13,618	5,117	93,982
1981	57,826	20,163	13,721	6,261	97,971
1982	57,826	22,115	13,721	7,366	101,028
1983	59,141	24,392	14,033	8,789	106,355
1984	60,455	24,933	14,345	10,268	110,001
1985	62,207	25,656	14,761	11,885	114,509

6.3 THE MEASUREMENT OF CONSUMER AND PRODUCER SURPLUSES

At this stage it is appropriate to consider briefly the implications of adopting such valuations in terms of the concepts of consumer and producer surpluses. First the general effects of a downward movement in a supply curve (as with all of the traits concerned) are described and the approaches to measurement adopted by some other authors are reviewed, then the methods of valuation adopted above are examined.

1. A Movement of a Supply Curve

Consider simply the benefits of one movement in a supply curve (Figure 6.1). Let the curve move from S_1 to S_2 (as often shown in the literature). Then working in areas, the benefits are apportioned:

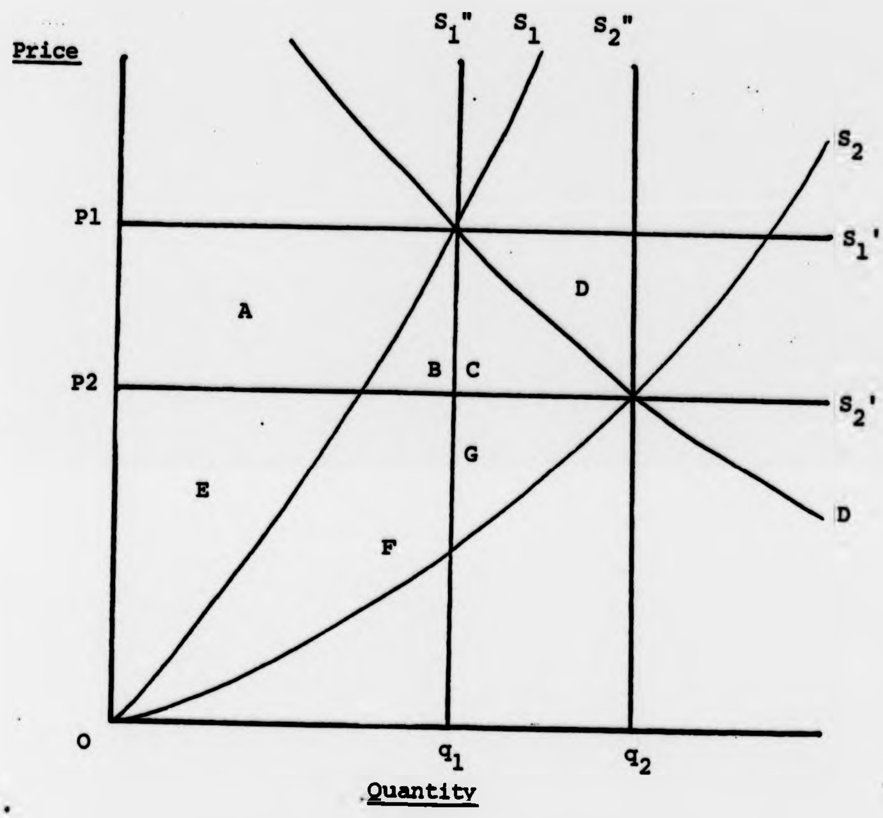
Change in consumer surplus = A + B + C

Change in producer surplus = F + G - A

Thus the net gain for society = B + C + F + G.

The estimation of this area will clearly depend on the assumptions made regarding the shapes of the supply and demand curves. In this respect it is important to note that past data can only provide guidance over very limited ranges of the supply and demand schedules. Any judgements regarding the shapes of the curves outside these ranges (in particular about the supply curves nearer the axes than there is past data for) must therefore depend greatly on the assumptions made. Looking at the assumptions made by authors in this area, the common approaches appear to be as follows:

Figure 6.1 Changes in Consumer and Producer Surpluses



a. Supply Curves:

Approaches made have basically been of two types:

a. To estimate the elasticity of supply over the range for which data exists and assume that this will be constant for the whole length of the curve.

b. To assume one of the two extreme cases of perfectly elastic or perfectly inelastic supply curves (ie S_1' and S_2' or S_1'' and S_2'' in Figure 6.1).

Griliches (1958) considered both perfectly elastic and perfectly inelastic supply curves and used the former as being the more conservative (this of course need not always be the case). The assumption of perfect elasticity was also adopted by Schmitz and Seckler (1970) and implicitly by Grossfield and Heath (1966). Ayer and Schuh (1972), Akino and Hayami (1975) and Flores Moya et al (1978) are examples of the alternative school. While the extreme cases of perfectly elastic or inelastic supply may seem unrealistic it may be questioned why the more sophisticated approach of assuming constant supply elasticity need be more accurate. Such an assumption implies supply curves passing through the origin which may also seem unrealistic. In practice then, any approach must necessarily be imprecise and the most appropriate will depend on the study in question.

b. Demand Curves:

The shape of the demand curve is clearly of much less importance than the supply curve (or curves) in that assumptions regarding it only affect the accuracy of the estimation of the area C (Figure 6.1). In past studies the common approaches have been to assume a straight line demand curve between the two points (as in Griliches, 1958), to assume a demand curve of constant elasticity (ie a rectangular hyperbola as in Akino and Hayami, 1975) or to ignore the area altogether as Schmitz and Seckler (1970) did, estimating the area (A + B + C + D) (overstating benefits by the area D) or Grossfield and Heath (1966) who effectively estimated the area (A + B) omitting C.

2. <u>Valuing Genetic Improvement in Pigs</u>

Consider now the above traits. Improvement in each trait has been valued per pig. This can be envisaged as a downward movement all along the supply curve for pigs. Diagramatically if the initial supply curve for pigs is S_1 in Figure 6.2a, after one year's improvement is seen in the commercial industry, the supply curve has moved to S_2. The process of multiplying improvement per pig by the number of pigs slaughtered may thus be seen to approximate the benefits for the extreme assumption of perfectly elastic supply (S_1' and S_2' in Figure 6.1). The more elastic the supply curve is the more accurate such an estimate will be. A priori it might be expected that the supply of pork would be quite elastic in the long term and published estimates seem to support this. Ferris et al (1971) estimate that a 1% change in the price of pork would lead to a change in the quantity produced of 0.97% after one year, 1.51% after two, and rising to 2.22% after five years. Jones (1961) estimates "long term" elasticities in the UK of "over 2.00%" for the period 1941 to 1958 and 3.61% for 1924 to 1939. The adoption of the simplifying assumption of perfectly elastic supply may therefore be seen as reasonable. Taking the numbers of stock actually slaughtered may lead to some

Figure 6.2a <u>The market for pork</u>

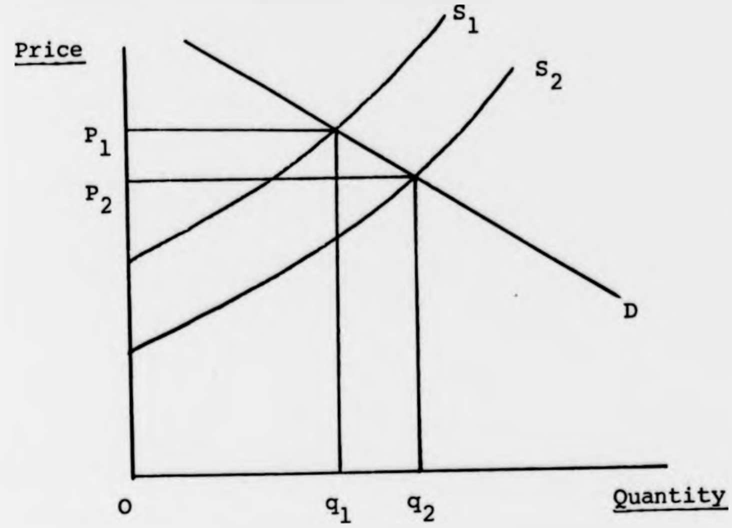
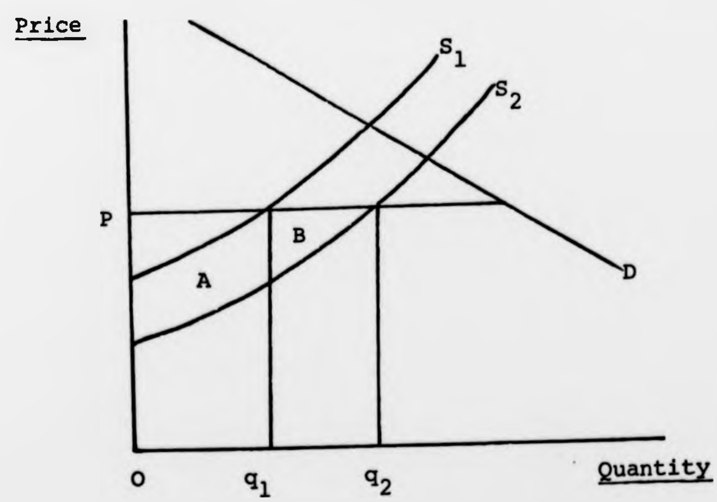


Figure 6.2b <u>The market for bacon and ham</u>



over-statement of benefits as improvement will have had some influence on increasing the numbers of animals produced (the difference between q_1 and q_2 in the figure) but this effect should be small compared with total benefits.

It must be noted, however, that the implications of improvement in pigs reared for bacon and ham are different from those raised for pork. In the case of an internationally traded good, as with bacon and ham, the situation is as illustrated in Figure 6.2b, where the original domestic supply curve is S_1 and the internationally determined price is p. (It is assumed that this price will effectively be insensitive to small changes in British production). At this price, domestic producers supply only a proportion of the market, Oq_1. As improvement lowers the domestic supply surve to S_2, then, the benefits are seen in an increase in the producer surplus of area A + B as domestic producers supply a greater proportion of the market (Oq_2). The market price is unaltered so there is no change in consumer surplus. Thus the method of estimating total benefits is less appropriate for the bacon and ham market. Given the methods adopted in the rest of the study, however, it is felt that this approximation must be accepted. It may be noted from Table 3.1 that the production of bacon and ham in Great Britain is only some 30 to 40% by weight of the production of pork (1973 to 1980) so it is hoped that the possible inaccuracy should not be unacceptable. The relative movements in the prices and consumption of pork and bacon will be examined in Chapter 9.

Chapter 7

THE COSTS OF PIG IMPROVEMENT

There are two stages in the evaluation of the costs relating to the various aspects of pig improvement in Great Britain. These are:

1. Defining the costs to be included.
2. Putting monetary values on these costs.

7.1 DEFINING THE COSTS TO BE INCLUDED

As described above the evaluation of the costs of pig improvement is to be made from the beginning of combined testing in 1966. In Chapters 4, 5 and 6 benefits have been estimated for continued investment in improvement work up until 1977 (with benefits after that year being the results of earlier investments). Costs are also estimated from 1966 to 1977 (inclusive) therefore, as if no further investment were to be made after 1977 and residual capital assets are re-evaluated and deducted from the total costs. There still exists problems with regards the boundaries of the system, however. The MLC's costs for central testing, the costs of the control herds and any additional costs to pig breeders through being involved in the scheme are clearly relevant. Since the work of selection by the independent breeding companies are included, their costs should also be counted. To what extent should the costs of other services provided to the pig industry be included however? Services such as the MLC on-farm testing service and artificial insemination service have key roles to play in the improvement scheme and are therefore counted. So too are the costs of the MLC commercial product evaluation tests, which enable monitoring of the independent breeding companies' progress. Less straightforward are the costs of research work by bodies such as the Animal Breeding Research Organisation (ABRO) and advisory services by the Agricultural Development Advisory Service (ADAS). It is argued that the current schemes represent the practical application of the results of research work such as ABRO's and it is largely through such application that the research has value. The costs of advisory work are also included for the value of such advisory work in widening the influence of such schemes.

7.2 EVALUATING THE COSTS

The main problem in evaluating costs is a reluctance by the bodies concerned to release detailed financial information. This applies particularly to the independent breeding companies. The approach adopted is to look at each body or group within the industry incurring costs relating to pig improvement and to estimate the costs for each individually. To bring costs to 1977 price levels the Gross Domestic Product implicit price level is used as an indicator of inflation (Table 7.1).

Table 7.1 Gross Domestic Product Implicit Price Level (Index based on 1975)

		Multiplier to bring to 1977 prices
1956	31.41	4.04
1965	41.42	3.07
1966	43.01	2.95
1967	44.21	2.87
1968	45.64	2.78
1969	47.27	2.69
1970	50.95	2.49
1971	56.43	2.25
1972	62.11	2.04
1973	66.83	1.90
1974	78.33	1.62
1975	100.00	1.27
1976	114.23	1.11
1977	127.01	1.00
1978	138.68	0.92

Derived from expenditure data, Table 5, Column 50; Economic Trends Annual Supplement, 1979 Edition.

7.2.1 The Meat and Livestock Commission

The Commission's costs can be divided under the following headings:

1. Central Testing
2. On-Farm Testing
3. Commercial Product Evaluation
4. Artificial Insemination Service.

A detailed breakdown of the costs under each of these headings would be useful as often an accountant's definition of costs can differ significantly from an economist's definition. Taking the final total from an operating budget without examination of the figures behind it can be misleading. Unfortunately the Commission is not able to release such detailed figures.

7.2.2 Central Testing

Costs are divided between capital costs (incurred in setting up the scheme) and running costs.

1. Capital Costs (D M Smith, personal communication)
The Central Testing Scheme is based on four testing stations. These were not built specifically for the current scheme, however, but for the preceeding progeny testing scheme. When they were built in 1956-57, the cost per station was approximately £120,000 each. From the point of view of the current scheme, this represents sunk costs, and the £120,000 per station would only be relevant if the stations could have been sold for that price in 1966. A fifth progeny testing station, also originally built in 1956, was sold in 1972 for approximately £70,000. Assuming

the other four stations could have been sold for the equivalent amount in 1966, then the opportunity cost of the stations was £70,000 per station (in 1972 prices). Thus the capital cost of the testing stations is taken as £280,000 in 1966 at 1972 prices, or £571,000 at 1977 prices.

In addition to the existing facilities, further accommodation at the stations was provided for the outdoor housing of boars in 1966 at a cost of £260,000. This converts to £767,000 at 1977 prices. Thus total capital costs in 1966 were £1.338 million.

No firm estimates of the current value of the stations are available, the specialised nature of the buildings making them difficult to value. If the stations were to be sold now, an estimate of current worth might be £150,000 each, making £600,000 for all the stations (Table 7.2, Column 1).

2. Operating Costs (D M Smith, personal communication)
The net deficit for the Central Test's operating budget has varied from year to year from a minimum of approximately £80,000 to a maximum of £160,000, with the average figure about £110,000 per year. Precise budget details are not available, but broadly speaking this figure includes the major items of cost to the MLC. These are the purchase of pigs, feed, labour, direct clerical cost, and many others. Returns from sales of both slaughter pigs and boars returned to breeders are deducted. Entry fees, transport costs and other costs are minor.

What is needed in this evaluation are the costs that would not have been incurred if no testing were done. The industry would still

Table 7.2 Costs at 1977 Prices (£000s)

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Year	MLC	Central Test	MLC on-farm Test	MLC	CPE	MLC	Control Herds	Nucleus Herds	Independent Breeding Companies		Additional Nucleus Costs	ABRO Research	ADAS R & D	Other Research	Total
	Capital	Operation		Capital	Operation	AI			Capital	Operation					
1966	1338	220					29	290				200	100	90	2,267
1967		220					29	290	975	36	11	200	100	90	1,951
1968		220				100	39	290	975	90	37	200	100	90	2,141
1969		220	70			100	39	290	975	144	63	200	100	90	2,291
1970		220	70			100	39	290	975	198	89	200	100	90	2,371
1971		220	70			100	39	290	975	270	119	200	100	90	2,473
1972		220	70	102	100	100	39	290		324	147	200	100	90	1,782
1973		220	70	(57)	100	100	39	290		360	150	200	100	90	1,662
1974		220	70		100	100	39	290		396	175	200	100	90	1,780
1975		220	70		100	100	26	290		396	175	200	100	90	1,767
1976		220	70		100	100	26	290		396	175	200	100	90	1,767
1977	(600)	220	70	(120)	100	100	26	290	(2,200)	396	175	200	100	90	-1,153

have to provide boars for breeding and many of the costs of feed, labour and other items would have to be incurred without any testing and selection work. Assuming that differences between prices paid by the MLC for weaner pigs at intake and prices received by the MLC for boars when they are returned to breeders roughly take account of these costs, the average net deficit on the budget can be accepted as a realistic estimate of the operating costs of the scheme (see Table 7.2, Column 2).

In addition some overhead costs must be allocated. Approximate annual figures are as follows:

Carcass work	£40,000 per year
Veterinary work	£20,000 per year
Statistics work	£20,000 per year
Computer operations	£30,000 per year

7.2.3 On-Farm Testing Service

This operation began in 1969 and 1977 budget figures for total costs are approximately £70,000 per year (£50,000 direct and £20,000 overhead). The primary value of the scheme was originally seen as providing a test for gilts in the nucleus and multiplier herds. In practice however, a great number of the potential breeding stock tested are in the commercial herds (perhaps some 40% of those tested) and these include many boars (nearly 20% of testing in 1978) (A Landon, personal communication). It has been shown that this work in the commercial herds is not cost-effective (A Landon et al, 1978), the costs exceeding the expected benefits. However, the additional costs, given that the service would exist anyway, would be fairly low (Landon, personal communication). It can be argued, further, that there are other grounds for such testing which can be justified, such as giving stockmen a feeling of involvement in selection policy and illustrating the worth of selection. The entire costs of on-farm testing are therefore included in the cost of the service to pig improvement (Table 7.2, Column 3).

7.2.4 Commercial Product Evaluation

1. Capital Costs

The CPE tests are carried out on a farm bought for £50,000 in 1972. Of this, £30,000 was realised by the sale of some of the land in 1973. The current value of the portion of the farm retained by the MLC is approximately £120,000 (D M Smith, personal communication). Table 7.2, Column 4 shows figures inflated to 1977 prices.

2. Operating Costs

The MLC's budget deficit on CPE should be a fairly accurate estimate of the additional costs incurred by running the scheme. The direct operating deficit is of the order of £45,000 to which overheads of about £55,000 per annum can be added (D M Smith, personal communication). Thus total costs per year are approximately £100,000 (Table 7.2, Column 5).

7.2.5 Artificial Insemination

To try to include all of the costs involved in providing AI services would be justifiable if the prime reason these services are provided is to help in spreading genetic improvement, but this is not so. The use of AI can be seen as an alternative form of breeding any stock (pedigree or commercial) from that of using natural service by farm boars and the argument that the industry would require boars for breeding irrespective of testing and selection work can be extended to the provision of AI services. Besides savings in the feeding, housing and handling costs of maintaining boars on a farm, further major reasons for using AI are to avoid health risks, by reducing the numbers of pigs brought onto a farm, and, in come cases, to cover temporary shortages of boars. The value of the genetic improvement produced through AI boars is offset by lower numbers of pigs per litter produced by AI. This suggests that the use of AI might have more to do with these latter reasons than genetic improvement. It might be expected, therefore, that AI services would still exist if no selection were practiced. On the other hand AI does fill a valuable role in spreading improvement to the commercial industry (see Chapter 5) and in making the best stock available to nucleus and breeding company herds.

Insemination services are provided by the MLC, the Ministry of Agriculture, Fisheries and Food (MAFF) and also by certain of the breeding companies. The companies may be expected to cover their costs in service fees and extending the argument that as the industry requires breeding stock anyway these fees may be ignored. The MLC's operation is subsidised to a small extent, however, and the AI centres of the MLC and MAFF incur further costs in research and development work. An estimate of these costs is £100,000 per annum (D M Smith, personal communication), see Table 7.2, Column 5.

7.2.6 Control Herd Costs

Estimates of the additional costs of running the two control herds are available since they have been financed by the MLC on a research budget. Total expenditures, less income from animals sold commercially, represents at recent price levels, £26,000 per annum for the two herds together (the Wye and Newcastle herds). The Newcastle herd was established in 1968 and the Wye herd in 1972. There had been an earlier control herd at Bangor (in operation until 1974) so that costs taken are as shown in Table 7.2, Column 7.

7.2.7 Additional Costs incurred by the Nucleus Herds

The nucleus herds incur additional costs through being involved in testing and selection work at the stations and in their own units. These costs must be weighed against the progress achieved. Rickard and Marks in a report to the MLC (1969) compared a normal 60 sow herd selling bacon pigs on the one hand, with an elite (nucleus) herd of the same size on the other. The additional costs for the nucleus herd were as shown in Table 7.3. Such estimates would overstate the additional costs, however. If no testing scheme were in operation the purebred stock would still be produced by specialist pedigree breeders. It is the additional costs of nucleus herds compared with these that are required. Thus advertising, breed society fees, recording and birth notification, and management costs would be incurred in any system. There may be additional transport costs (though not for all the nucleus herds) and certain specialised herd costs (D E Steane, personal communication).

Table 7.3 Additional Costs for a Nucleus Herd compared with a Commercial Herd (60 sow per herd)

	1969 prices
Additional boar costs	£ 265
Additional specialised herd costs	515
Advertising	200
Breed society fees	67
Recording and birth notification	38
Transport	564
Additional Management	200
	£ 1,849

Source: Rickard et al, 1969.

The estimates of costs shown for these herds will tend to be over-estimates, in as much as transport was estimated as the maximum likely and that some of the specialised herd costs may be inapplicable. Further, the estimates in the report were based on those herds most active in testing and selection work. The number of herds in the Central Testing Scheme has varied over time. Eighty herds was taken as an average figure which again is likely to over-estimate overall costs (D M Smith, personal communication). Thus the cost per year is taken as approximately £108,000 at 1969 prices or £290,000 at 1977 prices (Table 7.2, Column 8). After 1977, since no further selection is assumed, costs would be as for pedigree herd costs.

7.2.8 Multiplier Herd Costs

Here it may again be argued that the industry would still have to incur these costs if no testing and selection work were being carried out. It may be that some additional transport costs are incurred but these are minor.

7.2.9 Independent Breeding Companies

No costs were available from the independent breeding companies. An approximation is to base estimates on the costs of the Central Testing Scheme. As with the Central Testing Scheme, costs may be considered under different headings:

1. Selection costs - the costs of running a selection scheme, including capital costs.
2. The additional costs of operating breeding herds compared with normal commercial herds.

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2. The additional costs of operating breeding herds compared with normal commercial herds.

1. Selection Costs

The situation is complicated by the companies' continued involvement, to varying degrees, in the MLC's schemes. Certain companies may have certain cost advantages over the central testing scheme, for example lower transport costs, clerical costs, and perhaps, cheaper testing costs. However, expenditures may be higher in other areas, for example data processing and advertising. Since the current output of boars by the companies is approximately 1.8 times that of the central testing scheme (1974 - 1977, Table 5.3 above), the yearly selection costs of the companies are taken as 1.8 times those of the central test (Table 7.2, column 10). These are scaled down for earlier years roughly in proportion to the crossbred gilt sales estimated in Table 5.3 (taken as an indicator of the rate of growth of the companies). Estimation of capital costs is similarly difficult and again the MLC costs are scaled up (although no equivalent to the central testing stations exist and several of the companies make use of the central testing facilities). The original cost of the testing stations to PIDA is used since the companies would not have the MLC ready-made facilities. Capital investment is taken as even through the period 1967 to 1971 inclusive (Table 7.2, column 9).

2. Additional Costs of Running Breeding Herds

In Table 5.7 above the number of sows in the companies' herds was estimated as approximately 5,000. Scaling according to the number of 60 sow units this would imply estimated costs totalling about £175,000 per year are taken (with transport costs as in section 2.8 omitted). Scaling down for earlier years figures are as shown in Table 7.2, column 11.

7.2.10 The Animal Breeding Research Organisation (ABRO)

The budget for ABRO, the main research organisation involved in pig breeding research, for work on pigs has been approximately £200,000 per annum at 1977 prices (Table 7.2, Column 12). This estimate is based on the actual figures for the past five years.

7.2.11 Agricultural Development and Advisory Service (ADAS)

No cost figures are available from ADAS in relation to genetic improvement and advisory work with pigs. An estimate of £100,000 per annum is included (Table 7.2, Column 13) based on the scale of their operations.

7.2.12 Other Research

Other research costs in universities and colleges associated with pig breeding and improvement are estimated at approximately £90,000 (C Smith, personal communication).

Chapter 8

SYNTHESIS AND SENSITIVITY ANALYSIS

The major benefits and costs of pig improvement have been outlined above (Chapters 4 to 7). It is now necessary to compare these benefits and costs, and to consider how significant possible deficiencies in the data or in the methods used may be. First, costs and benefits are compared using various discounting criteria and discount rates, then a sensitivity analysis deals with such possible inaccuracies with regard to each of the stages of the study.

8.1 OVERALL SYNTHESIS

The choice of appraisal criteria was discussed in Chapter 2 with the conclusion drawn that the net present value (NPV) criterion is the most favoured by economists and it is adopted as the criterion for evaluation here. Other commonly used criteria are calculated, however, to allow comparison with other studies. The question of the choice of discount rate was also discussed in some detail in Chapter 2. Given that costs and benefits are measured in constant prices it was concluded that a rate of 5% would be appropriate (as recommended by the Government for use in the public sector, HMSO, 1978) and 5% is taken to calculate the initial NPV and for all calculations in the sensitivity analysis unless otherwise stated. NPVs are also calculated using a wide range of rates as part of the sensitivity analysis however.

Combining the benefits estimated in Chapter 6 with the costs estimated in Chapter 7 the resulting NPV with a 5% discount rate, for all benefits up to 1985 resulting from investments before 1978, is calculated as £915 million (see Table 8.1). The ratio of net benefits to costs is calculated as 32, and the internal rate of return (IRR) as 70% (approximately).

The scale of returns from investment reported in other areas of agricultural research and development has varied considerably, with very high returns reported in some cases (IRRs of up to 96%, with several above 50%; Table 2.3). Thus high as the estimated returns from pig improvement appear, they can be seen to be in keeping with results in these other areas.

8.2 SENSITIVITY ANALYSIS

With such disproportionate sums for benefits and costs it may appear unlikely that any single factor in the sensitivity analysis would challenge the overall conclusions of the study. The scale of changes in the estimate of NPV that may be produced by varying assumptions and estimates used is still of interest, however. To illustrate this scale the changes in NPV are calculated as a difference from the "base" NPV quoted

Table 8.1 Discounted Benefits and Costs (£ million)

1	2	3	4	5	6	7	8	9	10
Discount Rate (%)	Source of Benefits					Total Costs	NPV (6-7)	NPV percentage of NPV at 5%	Benefit cost (8/7)
	Company Style Dissemination	Traditional	Artificial Insemination	Remainder	Total				
0	641	204	155	70	1,070	21	1,049	155	50
2	609	191	147	65	1,012	24	988	108	41
5	572	174	139	59	944	29	915	100	32
10	531	154	130	52	867	41	826	90	20
15	521	141	127	47	827	57	770	84	14
20	509	134	127	45	815	80	735	80	9

above (with a 5% discount rate) and expressed as a percentage of that original NPV.

Items for consideration in the sensitivity analysis are:

1. The discount rate
2. The time period for analysis
3. The costs
4. Factors relating to the estimates of genetic change
5. Factors relating to the dissemination of that change
6. Factors relating to the value of that change
7. The imports and exports of breeding stock.

8.2.1 The Discount Rate

The absolute NPVs with a wide range of different discount rates, and those NPVs expressed as a percentage of the "base" NPV (at 5%) are shown in Table 8.1. In the context of the present study and within the range of discount rates which might reasonably have been adopted (between perhaps 2% and 10%) it can be seen that the choice of discount rate is not crucial to the conclusions that may be drawn regarding the value of pig improvement work (NPV being between 90 and 108% of the base NPV). As might be expected however, the differences in the discount rate examined can have a very significant effect on the scales of discounted benefits and costs individually. The figures are sufficient to emphasise the importance of choosing appropriate discount rates for investment appraisals in animal breeding. Comparing the contributions of each of the dissemination pathways to total benefits also emphasises how higher discount rates increase the preference for earlier benefits. Were undiscounted costs more substantial or benefits less substantial for a proposed project, or if a choice were being made between alternative projects, clearly the discount rate could be crucial. The higher rates examined in the table (which have been quoted by some authors in the animal breeding literature, see Table 2.1) could lead to an underinvestment in animal breeding improvement work and, perhaps, misdirected investment (comment is made elsewhere regarding the dangers of overselection).

8.2.2 The Time Horizon

The choice of time horizon is related to the discount rate. The decision to truncate benefits at 1985 has been taken as a way of dealing with uncertainty (both over the value of progress in the future and the scale of the industry in the future). An alternative method of dealing with uncertainty would have been to count benefits in perpetuity and load the discount rate with a risk factor (see Chapter 2). Such a method may be preferred since uncertainty increases with time and does not grow from zero to infinite uncertainty in one year (as truncation implies). However both methods are essentially arbitrary. Here a rather arbitrary cut-off point has been chosen for simplicity, so avoiding the problem of having to forecast the scale of the pig industry any further into the future.

To test sensitivity, NPVs with alternative cut-off points are calculated (0, 5, 10, 15 and 20 years) with all discount rates.

The alternatives of discounting to infinity are also calculated. For simplicity benefits per year after 1985 are taken as £110 million per year. Results are given in Table 8.2. Where higher discount rates are used to reflect uncertainty, discounting before 1977 should be with an unloaded discount rate (as no uncertainty now exists). The effect this would have can be seen from the first column (zero years projection) to be small.

These calculations are sufficient to illustrate the range of results that might have been obtained with alternative approaches, and as above, emphasise the possible importance both of the discount rate and the time horizon in such studies. The base NPV (to 1985 with a 5% discount rate) can be seen to approximately equate to discounting the benefits to infinity and loading the discount rate by 10 to 15%. Even the extreme and unrealistic case of truncating benefits in 1977 would leave the NPV positive even with the highest discount rate (20%).

8.2.3 Costs

The cost figures could not be accurately estimated (Chapter 7) but a sensitivity analysis can show whether these are important relative to the estimated benefits. Table 8.1 shows that costs would need to be understated by a factor of approximately 33 times to make the NPV negative, discounting at 5%. Even if total costs were doubled, NPV would only fall by 3.2%. Such an extreme error is unlikely. The aim has been to include all possible costs.

Table 8.2 NPVs with Alternative Time Horizons and Discount Rates (£ millions)

Discount rate	0	5	10	15	20	∞
	Projection (years)					
0	261 (29)	718 (78)	1,269 (139)	1,819 (199)	2,369 (259)	∞
2	271 (30)	700 (77)	1,171 (128)	1,596 (174)	1,981 (217)	5,682 (621)
5	287 (31)	680 (74)	1,053 (115)	1,346 (147)	1,575 (172)	2,404 (263)
10	314 (34)	657 (72)	916 (100)	1,076 (118)	1,176 (129)	1,340 (146)
15	345 (38)	645 (70)	828 (90)	920 (101)	956 (105)	1,010 (110)
20	375 (41)	642 (70)	774 (85)	827 (90)	848 (93)	862 (94)

Figures in brackets NPV, as percentage of base NPV (5% discount rate, projected to 1985).

Benefits per year to 1985 taken as £110 million for simplicity.

It has been noted by Hertford and Smitz (1977) that in many of the studies in agricultural research (see Chapter 2) gross benefits have been set against only the direct costs of research, omitting or reporting only in part the costs of implementation. In this case a development project is being considered, (rather than the research projects Hertford and Smitz referred to) and costs include those of implementation and research work.

8.2.4 Factors relating to the estimates of genetic change

A number of possible criticisms of the estimates of genetic change used have been considered in Chapter 4 (above). An attempt is made here to examine the effects such factors may have quantitatively. The following factors are considered:

1. Statistical variance
2. The final slaughter weights of stock varying from that used in the central test
3. The effects of differences in diet and feeding regime from that used in the central test
4. Possible increased sow weight brought about by selection
5. More recent estimates of genetic change from those used.

1. Statistical variance

While estimated standard errors about the regression of progress on time are available for each of the individual traits in the central test, the MLC is not able to provide a comparable figure for the total value of progress per pig per year (D Jones, personal communication). An attempt was made to estimate such a figure based on the simplifying assumption that the estimates for individual traits are independent of one another. This yielded an estimated standard error of approximately 5p (D Jones, personal communication). An alternative simplification is to calculate the standard error for the two most significant traits (feed conversion ratio and lean percentage, which together account for 61p of the overall estimate) and scale up. This gives an estimate of appropriately 10p (C Smith, personal communication). Thus the 95% confidence limits for progress are:

65 - 85p using Cook's estimate

or 55 - 95p using Smith's estimate

Taking the lower limit in each case, NPV becomes £789 million (86% of the base NPV) or £663 million (73%) respectively.

2. <u>Final Slaughter Weight</u>

The total benefits may be over-estimated by assessments at a 90 kg slaughter weight when in the industry, pigs are slaughtered to a variety of weights, with an estimated average being 80 kgs (Table 3.2). Linearly scaling down the estimated benefits, the 75p annual progress figure would become approximately 66p. This would give an NPV of £802 million, 88% of the base NPV.

3. <u>Diets and Feeding Regimes</u>

The type of diet and feeding regime used in the control test may be inappropriate for comparing improved and unimproved pigs. It might be argued that any economic comparison should be made with each type of pig on its optimum production system (R Fawcett, personal communication). Such a criticism would be valid if commercial farmers used the feeding regime and feed quality to maximise revenue for a particular quality of pig. To some extent feed quality is now standardised in the industry (D Steane, personal communication) so that it might be difficult for breeders to find and use such feeds. As with other aspects of pig improvement, it is a matter for conjecture what qualities of feed and what feeding practices would pertain in the industry if genetic improvement had not been made (eg whether generally lower quality feeds would be the norm). Thus the validity of this criticism is not certain.

An attempt to gauge the the possible effects of this factor was made with the aid of the Edinburgh Pig Model (Whittemore and Fawcett, 1976). Two qualities of ration and three feeding scales were used (Table 8.3). Profit was calculated per pig place. Comparing each type of pig at its most profitable, the difference in profit per place was £13.2. If comparison is made with both types of pig, on high quality ration with high feeding levels (as in the central test) the difference would be £19.7 per place. Thus scaling down the estimate of improvement made (75p per year) in ratio (13.2 to 19.7), benefits per pig per year may be estimated as only 50p. This would yield an NPV of £600 million or 66% of the base NPV.

4. <u>Sow Weight</u>

Improvement in growth and carcass traits might be partly offset by unfavourable correlated genetic effects on sow weight. It may be argued:

Table 8.3 <u>The effects of feed quality and feeding regime on improvements achieved</u>

(Calculations based on the Edinburgh Pig Model, reported by Whittemore and Fawcett, with input variables used).

Ration - gms of digestible crude protein per kg	Feed Scale	Profit per pig place per year (£)		Difference in profit (£)	Difference at optimum *
		Unimproved	Improved		
110	Low	17.02	21.98	4.96	13.20
	Medium	18.87	28.09	9.22	
	High	19.32*	32.28	12.96	
140	Low	13.70	27.71	14.01	
	Medium	14.00	31.65	17.65	
	High	12.81	32.52*	19.71	

Feeding scales used:

Low	1.2 kgs/day, rising by 0.1 kg/week to a maximum of 2 kg/day
Medium	1.2 kgs/day, rising by 0.15 kg/week to a maximum of 2.2 kg/day
High	1.2 kgs/day, rising by 0.2 kg/week to a maximum of 2.4 kg/day

Prices (p/kg) for different carcass grades:

A1	82.6
B1	79.7
B2	77.6
C	73.7

Growth rates:

Improved stock	520 gms lean per day
Unimproved stock	400 gms lean per day

a. That sow weight can be controlled by restricted feeding; and

b. That any changes in sow weight will be economically unimportant because they are spread over two litters (16 pigs) per year. This argument is obviously sufficient for any increase in boar weight, one boar being sufficient to serve over twenty sows per year.

The first argument may be rejected because the level of feed fed to maintain body weight and condition for breeding is determined by those factors themselves. Thus large framed sows would be starved and small sows would become fat on the same restricted level of feed.

To test the validity of the second argument some approximate calculations were carried out by C Smith (personal communication). The arguments, with figures comparable to those used in the estimates of total benefits, are reproduced here. Selection methods leading to increased sow weight might also lead to an increase in age for weight and sexual maturity. This would result in increased feed costs. To simplify the calculations it is assumed that these increased costs are offset by the value of the extra weight of carcass from the sow at slaughter. It is also assumed that there is no genetic correlation between sow weight and litter size.

For simplicity, selection for the combined test index is considered. The genetic responses in index (I) and in sow weight (W) from one round of selection on (I), with selection differential $i\sigma_I$, are:

$$\Delta G_{I.I} = i\, h^2_I \sigma_I$$

and $$\Delta G_{W.I} = i\, h_W h_I r_{G_{WI}} \sigma_W$$

where h^2_I = heritability of I

h^2_W = heritability of W

$r_{G_{WI}}$ = the genetic correlation between W and I.

The value of one phenotypic index point is 2.7p (Cook, personal communication), so the value of a standard deviation unit (35 points) is 95p. The total value of the direct response with an index heritability of 50% and with 16 pigs per sow per year, is:

$$i(95)(0.5)(16) = 760\ i \text{ (pence) per sow per year.}$$

The value of one phenotypic standard deviation (σW) change in sow weight is:

Feed cost at $(W+\sigma W)$ - Feed cost at (W)

$$= K\ ((W+\sigma W)^{0.75} - W^{0.75})\ )$$

$$= K\ W^{0.75}\ ((1+CV_W)^{0.75} - 1)\ )$$

where CV is the coefficient of variation for sow weight, and K is a constant. It is assumed the feed required is proportional to body weight to the 0.75 power. Maintenance feed costs per sow per year, at 2.3 kgs feed per day, and feed cost of £120/tonne, is then £(2.3)(0.12)(365) = £101. This is equivalent to $KW^{0.75}$ above. The value of the indirect response in sow weight (heritability of 50%) is:

$$i\sqrt{(0.5)(0.5)}\ (r_{G_{WI}})KW^{0.75}((1+CV_W)^{0.75} - 1)$$

$$= (5050)\,i\ ((1+CV_W)^{0.75} - 1)\ r_{G_{WI}}$$

This can then be evaluated for different values of the coefficient of variation and the genetic correlation, as in Table 8.4.

With the sets of parameters used, which are considered conservative, any indirect genetic increase in sow weight can reduce the value of direct responses by 10 to 30%. Taking the two extremes shown in the table, the estimate of progress per pig per year would lie in the range 54p to 71p. NPV would then be £651 to £858 million (71 to 94% of the base NPV). If these figures are correct this factor should be taken into account. Lack of firm data on the genetic correlation between sow weight and progress, and on the coefficient of variation in sow weight means that these results are tentative. As with other factors an experimental check would be necessary to give more precise figures.

5. <u>Later estimates of genetic change</u>

More recent figures from control herd comparisons published by the MLC (D Jones, 1979) indicate lower estimates of genetic progress than those used above. The estimates are for the period January 1974 to June 1979 and are given in Table 8.5. Using the same economic weights as before the estimated genetic progress per pig per year is approximately 56p for the Large White breed and 64p for Landrace. Assuming an LW (LWxL) cross as being the norm in the final generation, this would mean a weighted progress figure of 58p (compared with the 75p figure used for Table 8.1) giving an estimate of NPV of £701 million (77% of the base NPV).

Table 8.4 **Estimates of the economic effect of Genetic Increases in Sow Weight following selection on the MLC index**

Coefficient of variation for mature sows weight CV_w	Genetic Correlation r_{GWI}	Value of Response			
		Direct Response (p)	Indirect Response (p)	Net Response (p)	Net/ Direct (%)
0.08	0.7	760	210	550	72.4
	0.5	760	150	610	80.3
	0.3	760	90	670	88.2
0.04	0.7	760	105	655	86.2
	0.5	760	75	685	90.1
	0.3	760	45	715	94.1

Table 8.5 <u>Later estimates of genetic change</u>

Trait	L.W.	Estimated Standard Error	Value p	Land.	Estimated Standard Error	Value p
Feed Conversion Ratio	0.00597	0.00650	5.2	0.00994	0.00771	8.6
Daily Gain	-0.00051	-0.00200	0.3	0.00040	-0.00243	0.2
Killed Out %	0.154	0.0637)	13.2	0.272	0.0694)	15.7
Trim %	0.0625	0.0224)		-0.0246	0.0252)	
% Lean	0.690	0.238	38.0	0.721	0.257	39.7
Total			56.4p			64.2p

Source: Jones (1979)

Examination of these estimates of genetic change show them to be far from satisfactory. Over the shorter period the estimated standard errors on some of the traits are very large. Jones investigated the results for evidence of departures from linearity in progress. He found changes in Large White results to be linear for the carcass traits, but not for feed conversion ratio and daily gain. The Landrace figures show significant curvilinear trends for almost all characters. These results show a period of rapid improvements (1974 - 1977) followed by an apparent deterioration, so that by 1979 nucleus pigs looked only marginally better than 1974 pigs, and worse than 1976 pigs. However, on genetic grounds, negative trends in the nucleus population are quite unlikely. Difficulties in maintaining the required mating patterns in the control herds and possible changes in the herds making up the nucleus populations are also unlikely to account for the observed results. Another possibility is changes in pre-test environment and the effects on the test results. The ideal situation would be if control pigs and nucleus pigs could be raised in the same environment. However in practice they are on different farms. Changes have taken place over the period in weaning age and the type of creep feed (used for small piglets) used by the control herds. In general these changes did not appear to correspond with the trends in genetic change.

6. Conclusions

A totally satisfactory explanation of the more recent lower estimates of genetic progress is not available, though there must be considerable doubt regarding their accuracy. Regarding the other arguments, if these are all accepted, then they may be combined as follows. Any effect on sow weight will be seen irrespective of the final weights of the slaughter generation, and the appropriate feed for "improved" breeding stock would be the higher quality feed. Thus the reduction in benefits due to an increase in sow weight may be accepted in absolute terms irrespective of the other factors, which will affect the benefits achieved at the commercial level proportionately. Thus accepting the arguments regarding sow weight, feeding regime and slaughter weight (the total cost of increased sow weight plus the percentage decreases in the progress per pig per year figure due to the other factors) yields an NPV of £260 million (28% of NPV). Hence even with the most pessimistic assumptions here it appears the NPV is still positive, although a number of factors which may be very important have been highlighted. In most cases more accurate figures would require experimental data.

8.2.5 Dissemination

The figures used in tracing the dissemination of improvement to the commercial industry in Chapter 5 were the best estimates available from contacts with the MLC and other sources. While most of these figures are quite precise some estimates are more doubtful. The calculations have been carried out to test the effect on NPV of adopting possible alternative estimates at various points. In many cases the effects are trivial and a detailed description of these factors is not included here. Factors which are considered here are:

1. The relative qualities of breeding stock passing down each pathway
2. The use of the offspring of purebred gilts sold to the commercial industry
3. The lengths of life of breeding stock in the national herd
4. The artificial insemination pathway
5. The "remainder" of the industry.

1. <u>The Qualities of Stock Passing Down each Pathway</u>

If no account were taken of the different qualities of stock passed down each pathway it might be assumed that all stock leaving the nucleus level was of average nucleus quality (ie an equivalent of 100 points in the central test index). This would yield lags as follows (the estimates used above given in brackets):

Company style pathway	2.8 years	(2.2)
Traditional style pathway	7.3 years	(5.9)
Artificial insemination pathway	5.4 years	(3.0)

The NPV with these longer lags is £795 million (87% of the base). This is too pessimistic, since there is selection of stock, and the average would be above 100 points. Taking the average quality of males left after culling as 120 points in the central test, the lags would be:

Company style pathway	2.2 years
Traditional style pathway	6.6 years
Artificial insemination pathway	4.7 years

Thus NPU would be estimated as £867 million (95% of base NPV).

2. The Offspring of Purebred Gilts

It has been assumed that on average from each litter a purebred sow produces two crossbred gilts which will take their places in the national herd. This figure is based on the best estimates available but may be open to some question. Possible averages of 1.5 gilts per litter and 1 gilt per litter are considered for sensitivity. With 1.5 gilts per litter the estimate of discounted benefits from the company style pathway falls by £82 million. Using the same methods as above to recalculate NPV, however, there is an offsetting increase in the benefits from the traditional style pathway of £61 million. Thus NPV overall falls to £894 million (98% of the base NPU). When only one gilt per litter is assumed the effect is approximately double.

3. The Lengths of Life of Breeding Stock in the National Herd

Altering the estimates of average lifespan affects both the estimates of average lags and the proportions of the industry estimated to be following the different pathways. Three separate estimates of lifespans in the herds have been used above (Chapter 5):

Purebred gilts	2	years
Crossbred gilts	2.5	years
Boars	2	years

The estimate for purebred gilts is unlikely to be inaccurate. For boar life, however, while two years has been taken as the best estimate a figure as low as 1.5 years might be supported (D Steane, personal communication). For crossbred gilts an alternative figure of 2.25 years might have been used (D Steane, personal communication). -

As above revision of the estimate of gilt life would lead to a reduction in the estimates of the proportion of the industry affected by the company style pathway but an increase in the proportion affected by the traditional style pathway. In addition, the estimated average lags would be reduced.

Changing the estimate of average boar life reduces the lag for and the proportions affected by both the company style and traditional style pathways. In this case assumptions regarding the remainder of the industry become more significant as the size of that remainder increases. Combining a boar life of 1.5 years, an average of 1.5 crossbred gilts from each purebred sow's litter, and a crossbred sow life expectancy of 2.25 years, estimated benefits from the company style pathway fall by £122 million and from the traditional style pathway by £33 million. With the same assumptions regarding the remainder of the industry, the estimated benefits from that sector increase by £78 million. Thus overall NPV is still estimated as £838 million (92% of the base NPV).

4. <u>Artificial Insemination</u> (AI)

Compared with the company style and traditional pathways opinions with regards the AI pathways are much more divided. In particular two major areas of doubt exist:

a. The proportion of inseminations used to produce parent stock

b. The kind of parent stock inseminations are used to produce.

Dealing with each in turn:

a. Proportion of Inseminations:

D Smith (personal communication) suggests that the proportion of total inseminations used to produce parent stock may be as low as 25% (instead of the 60% used in the main study). On this basis, the estimate of benefits from the AI pathways falls by £50 million. The net effect is an NPV of £865 million (95% of base NPV).

b. Type of Stock:

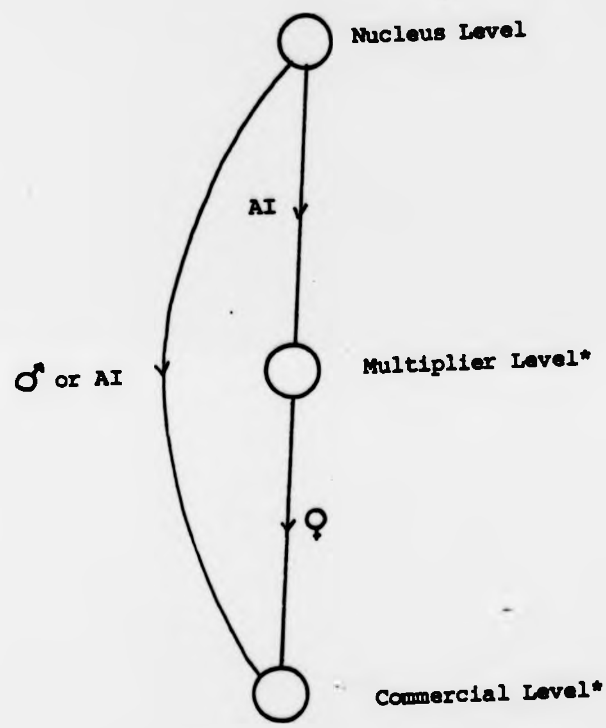
An alternative pathway suggested (D Steane, personal communication) is one in which AI is used to produce crossbred gilts only, and these are mated either with brought in boars or are also inseminated artificially (see Figure 8.1).

Alternative calculations were carried out on the following basis:

1. 25% of AIs are used to produce gilts only (including the purebred gilts needed to parent crossbred gilts). If 60% were used in this type of pathway the figures would be totally unrealistic in terms of the number of gilts resulting.
2. 40% of the rest of the AIs are used to inseminate the gilts produced.
3. The rest of the boars required are bought in (ie borrowed from the traditional style pathway).

Compared with estimates with 25% of inseminations used in the original type of dissemination pathway, the lag is shorter but the proportion estimated as affected by the traditional style pathway is reduced. The net effect is a further reduction of £11 million in NPV so that the combined effect is NPV falling to £854 million (93% of base NPV).

Figure 8.1 An Alternative Artificial Insemination Pathway



* Both within the Commercial Level.

5. The Remainder of the Industry

Although the assumptions used above are arbitrary regarding this section of the industry it may be noted that discounting benefits before 1985 at different discount rates this section of the industry only contributes from 6 to 7% of total NPV and if omitted NPV at 5% would still be £858 million. However as other assumptions are varied, the importance of this sector of the industry increases. With the revised assumptions outlined above regarding lifespans of breeding stock and the offspring of purchased purebred sows, omitting the remainder would reduce NPV to £701 million (77% of base NPV). With the alternative assumptions regarding AI, NPV would fall to £776 million (85% of base) omitting the remainder.

6. Conclusions regarding the Dissemination Process

The conclusion with regards tracing the dissemination process must be that any likely errors at this stage should not be significant. Many areas of doubt do exist. When these are considered, however, it appears that, given the likely ranges within which possible errors in estimates must lie, none of these doubts are too important. In general the figures relating to the company style and traditional pathway, should be fairly accurate. While the situation is less satisfactory with regards the other two pathways, together they only contribute 22% of the base NPV. Even given fairly pessimistic revisions of estimates no factor in isolation reduces the estimate of NPV by more than about 5%, although in some cases more emphasis is placed on the remainder of the industry. Taking the extreme case of assuming no benefits from the remainder of the industry, the lowest NPV ever falls is 77% of the original NPV.

8.2.5 Factors relating to the Value of Progress

The economic weights used were discussed in Chapter 6 above. The basic values in the MLC's calculations were checked and found accurate for the base year of 1977. This section deals with the sensitivity to possible inaccuracies from two sources:

1. The possibility that the relative economic weights have changed through time.
2. Those traits where it was concluded above that there might be some question over the value of progress.

1. Changing Values through Time

The MLC have periodically updated their economic values over time and a list was available. The MLC's arguments quoted above (from Cook, 1977) would give a slightly different estimate of the value of progress per pig per year from that adopted in the main part of the study (77p instead of 75p). The reasons for this difference were outlined in Chapter 6. Clearly this difference is trivial. Using the earlier economic weightings supplied by D Jones and inflating to 1977 prices, the figures comparable to this 77p figure varying between 51p and 86p. Adopting the lowest figure the estimate of NPV would still be approximately £600 million (66% of base NPV).

2. Individual Traits

In Chapter 6 the relevant prices behind the monetary values used for feed conversion ratio, killing out percentage and trimming percentage could easily be confirmed by reference to actual data from the industry. The value behind the other traits measured in the central test are less straightforward.

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2. Individual Traits

In Chapter 6 the relevant prices behind the monetary values used for feed conversion ratio, killing out percentage and trimming percentage could easily be confirmed by reference to actual data from the industry. The value behind the other traits measured in the central test are less straightforward.

1. Eye Muscle Area:

   This is included in the central test as it is felt by the MLC to have some value to the meat trade. No meaningful value can be placed upon it, however, and the MLC's index weighting of 3p per square centimetre is arbitrary. It may be noted that if this value were incorporated in the analysis the increase in estimated progress per pig per year would only be 0.8p, making a difference of only 1% to NPV.

2. Daily Gain:

   The value adopted in the study above was lower than adopted using the MLC's arguments (for reasons outlined in Chapter 6). The effect of differences in this value can be seen to be small however. Using the MLC's argument NPV would only rise by £19 million (2% of base NPV). Omitting daily gain altogether would only reduce NPV by £40 million or 4% of base NPV.

3. Lean percentage:

   As mentioned in Chapter 6 the value of lean percentage was the subject of a study by J Chadwick (personal communication) and was felt to be quite accurate. It may be noted, however, that even though lean percentage is the single most important trait in terms of estimated progress, the other traits put together would alone give an estimated NPV of £442 million (48% of base NPV) meaning that the investment was still wholly justified even omitting lean percentage.

8.2.6 Imports and Exports of Stock

International trade in breeding stock could be important in assessing the value of investment. If improved stock were brought in from abroad then it would be inappropriate to accredit all improvement made in Great Britain to British investment. Similarly exports of British breeding stock are an additional benefit. The value of breeding stock involved is taken as an estimate of additional costs and benefits.

Estimates of exports of breeding stock are given in Table 8.6 (from D Steane, personal communication). Taking figures of 1,000 boars per annum and 8,000 gilts after 1977 and valuing these at £200 each (approximately the price less production costs) the total increase in NPV at 5% can be calculated as £39 million (an increase of 4%). Imports of stock over the period have been negligible.

8.2.7 Conclusions on the Sensitivity Analysis

The sensitivity of the study has been tested in relation to a wide variety of issues. The general conclusion must be that the investment has been proven worthwhile. Many areas of doubt have been shown to be relatively unimportant. Others have been shown to be possibly more significant, but several pessimistic revisions of assumptions must be put together before calculations of NPV can be made negative. This is perhaps not surprising given the starting figures. A much less detailed examination of the value of progress might have been enough to reach this overall conclusion. The study is of value however in allowing several areas of doubt to be dismissed and in highlighting several other areas where better knowledge would be valuable, such as the possible effects on sow weight and different diets. These particular areas hint, however, at a broader criticism that may be levelled at this study. The method of following the improvements achieved in the testing herds through to the commercial farm level assumes that the commercial farms will realise all of these potential benefits. For various reasons, not all of which may have been identified here, the full attainable benefits may not have been achieved by the commercial industry. Given the approach of this study it is only possible to give a conservative estimate of the potential benefits of the genetic improvement achieved centrally. It cannot be confirmed to what extent these benefits have been realised by the commercial farms, though again it would be extremely pessimistic to think that the real benefits achieved were not sufficient to justify the investment.

Looking at past improvement in this way also leads to the more important question of implications for the future and a number of wider issues which are discussed in the following chapter.

Table 8.6 Exports of Breeding Stock (including Independent Breeding Company Exports)

Year	Boars	Gilts
1969	400	1,400
1970	1,150	8,250
1971	1,400	8,800
1972	1,450	12,600
1973	2,000	15,000
1974	1,400	19,800
1975	750	14,300
1976	800	14,500
1977	1,350	8,100

Source: D Steane, personal communication.

Chapter 9

DISCUSSION OF SOME WIDER ASPECTS

The study above records the estimated value of past investment in pig improvement. Of further interest are:

1. The value of future investment; and
2. Some of the wider issues involved.

The purpose of this chapter is to discuss these issues. This is done in five main sections:

1. The distribution of benefits
2. The value of future investment in pig improvement in Great Britain
3. Public versus private investment
4. Possible future changes in breeding objectives
5. International considerations.

9.1 THE DISTRIBUTION OF BENEFITS

Where the benefits have gone is a question of interest for two reasons:

1. It would be reassuring if the benefits estimated could be accounted for.
2. If this question can be answered it may have implications for the future of investment in pig improvement.

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Where the benefits have gone is a question of interest for two reasons:

1. It would be reassuring if the benefits estimated could be accounted for.
2. If this question can be answered it may have implications for the future of investment in pig improvement.

As discussed in Chapter 6 the benefits will be divided between the different parties involved (improvement herds, commercial farmers, the butchering trade and the final consumers). To try and aportion the benefits between these groups would involve a detailed study of supply and demand elasticities at different stages which is outside the scope of the present study.

While precise evidence is missing, however, some general comments may be made here. In Chapter 6 it was suggested that there was some documentary evidence to suggest that the supply of pork is quite elastic. This would be consistent with the consumer being the major beneficiary of progress. Several animal breeders have stated an opinion that in general competition leads to the benefits of improved stock going to the consumer through lower prices and greater quantities consumed (Steane, Chadwick, Moav, Soller; all personal communications). Possible support for these claims may be found by looking at changes in the price and consumption of pork over the years as compared with other meats. Figures are shown in index form in Tables 9.1 and 9.2.

A clear trend can be seen for the price of pork to rise less quickly than that of mutton and beef, and for its consumption to increase over the period (probably due to the relative price changes in the main but perhaps in part because consumers' tastes have changed as the meat has become less fatty). The picture is one that might be expected if the progress estimated had been achieved and the consumer had reaped most of the benefits. The scale of the benefit may also be seen as consistent with that claimed. 75p progress per pig per year for eleven years would mean a difference of approximately 7p per pound at 1977 prices.

Table 9.1 Retail Price Indices of Major Meats

Year	Beef	Lamb	Pork	Bacon and Ham	Broilers
1960	95	97	99	99	
1961	96	95	100	97	
1962	98	98	98	96	
1963	99	100	98	100	
1964	111	109	104	108	
1965	122	116	105	108	
1966	127	120	114	115	
1967	127	118	120	119	133
1968	140	128	124	121	133
1969	149	138	129	128	123
1970	155	142	138	136	127
1971	175	156	145	154	139
1972	197	180	162	165	135
1973	255	232	205	221	174
1974	255	264	216	260	195
1975	265	286	270	309	237
1976	344	338	299	360	271
1977	383	394	320	374	322
1978	438	457	377	407	353
1979 (9 months)	483	493	390	441	399

Indices based on an average of 100 points from 1960 - 1964.

Broilers adjusted so that the average for the period 1967 - 1971 is the same as for pork (earlier figures not available for broilers separately).

Figures based on National Food Survey data.

Table 9.2 Per Capita Consumption of Meat

Year	Beef	Mutton	Pork	Bacon and Ham	Broilers
1960	97	101	91	99	
1961	101	103	88	98	
1962	100	103	103	104	
1963	106	97	112	100	
1964	95	96	105	99	
1965	90	90	126	101	
1966	90	95	124	99	101
1967	95	92	103	96	110
1968	86	87	113	96	121
1969	86	81	125	95	127
1970	86	79	126	98	132
1971	87	81	135	94	123
1972	77	91	140	87	140
1973	70	68	136	82	151
1974	83	63	145	78	138
1975	93	65	123	74	144
1976	84	64	129	75	151
1977	92	60	149	81	152
1978	92	60	151	81	158
1979 (9 months)	92	63	160	82	162

Index based on average of 100 points for years 1960 - 1964.

Broilers adjusted to give the same average as Data for years 1966 - 1970.

Figures based on National Food Survey data.

The difference in price between pork and beef at the retail level in 1977 was 16p per pound, while prices per pound had been approximately the same in the early 1960s.

Since there has been little genetic improvement in beef or mutton production over the same period these meats may be taken as some indication of how pork might have faired without genetic improvement. It must be stressed, however, that such a straightforward comparison ignores too many factors to be taken as reliable evidence (changes in husbandry techniques, veterinary practices, political factors, market cycles, feed and labour costs etc). Nonetheless it is reassuring that the figures are consistent with the estimated results.

Comparative figures for broiler chickens for the same period are not available, but a shorter series of figures are shown with some adjustment made to give comparability. These are of interest since significant genetic progress has also been made in broilers. It may be noted that a similar picture emerges to that with pork with falling prices, in comparison to other meats, and increasing per capita consumption, though improvements in husbandry techniques have undoubtedly played a significant role too.

In Chapter 6 it was noted that the benefits in terms of bacon and ham would be seen in terms of a greater share of consumption being met by domestic production. This would not be illustrated by these tables. The fact that bacon is a traded good is a possible explanation of why bacon prices have risen more rapidly than pork.

The suggestion that improvements made at the farm level benefit the consumer most is perhaps significant in terms of policy decisions on the desirability of future investment from the point of view of the nation as a whole.

9.2 THE VALUE OF FUTURE INVESTMENT IN PIG IMPROVEMENT IN GREAT BRITAIN

The main study allows some comments to be made on the desirability of future investment in pig improvement. The assumption was made in the study that the rate of improvement in the nucleus herds has been approximately equal in each year. Clearly as long as it can be assumed that progress can be maintained at the same rate (75p per pig per year) future investment on the same scale can be justified. This can be illustrated by considering one more year's investment in isolation. The following assumptions are made:

1. Variable costs are as shown for 1977 in Chapter 7.
2. Capital costs are estimated as the potential return on the capital "recouped" in 1977 in Chapter 7 over one more year.
3. The dissemination pattern estimated for 1977 is used.
4. The value of one year's progress is taken as 75p per pig per year.
5. The estimated lags for the early years of investment (Chapter 5) are used.
6. An annual slaughter rate of 13 million pigs is taken for simplicity.

Costs for one year are thus estimated as in Table 9.3. Benefits for ten years after the selection year are estimated as shown in Table 9.4. NPV can thus be estimated as approximately £17 million after five years, or £49 million after ten years at a 5% discount rate, or £14 million or £36 million respectively at a 10% rate. In either case investment would be paid back in Year 3.

Table 9.3 **Costs of one year's Investment**
(based on figures presented in Chapter 7)

	£000s
Central test (operating cost)	220
On-farm testing	70
CPE (operating cost)	100
AI (by MLC)	100
Control herds	26
Nucleus herds	290
Independent Breeding Companies (total operating costs)	591
Research (total)	390
Allowance for opportunity cost of capital	146
	£1,933

Table 9.4 **Benefits from one year's Selection**

Years after Selection Year	Benefits £m (rounded to nearest 0.1)			
	0%	5%	10%	(Discount Rate)
1	-	-	-	
2	1.0	0.9	0.9	
3	5.5	4.7	4.0	
4	7.8	6.4	5.3	
5	8.8	6.9	5.5	
6	8.9	6.6	5.0	
7	9.1	6.5	4.7	
8	9.4	6.4	4.4	
9	9.6	6.2	4.1	
10	9.8	6.0	3.8	

In Chapter 8, the Sensitivity Analysis, a number of areas of doubt were illustrated which could mean total benefits have been over-estimated, however. The conclusions drawn were that in looking at past investment these areas of doubt were not so great as to bring into question whether that investment had been worthwhile. In looking at future investment, though, these areas may become more significant, in particular as the assumption of linearity of progress becomes inappropriate. There must exist limits to which genetic progress can be made in specific characteristics, and as these are approached the annual rate of progress in the improvement herds can be expected to fall. Indeed, the recent estimates of genetic progress published by Jones (1979) have been less than earlier estimates. Thus, even given the very positive results shown here, some effort to quantify more accurately the effects of related increased sow weight, the use of AI, different feeding methods, and the other factors highlighted earlier may be justified. In particular as time goes by, the importance of keeping some check on the rate of improvement made in the improvement herds will become more important. It is unfortunate that the MLC have been forced to cease their financial support for the control herds, but there are plans to freeze semen from these herds so that control pigs will be available in the future (C Smith, personal communication).

9.3 PUBLIC VERSUS PRIVATE INVESTMENT

While conclusions regarding the value of past improvement have been made it is not possible on the figures available to draw any conclusions on whether the investment made has been to the best effect. The purpose of this section is to discuss one particular aspect of this area with particular relevance to the future: the duplication of effort by public and private bodies. The development of a number of breeding companies has been described above which are largely independent of the MLC central testing scheme and other services. While the central test and related services had much to do with their development, questions might now be asked regarding the value of keeping these services alongside the independent companies:

1. Is central testing still making a significant contribution to pig improvement in Great Britain?
2. Could improvement now be left to the private sector, and if it could, should it be?

As described above it is not possible to aportion benefits between the breeding companies and the central testing scheme. With costs, those estimated for the breeding companies are based on MLC costs. Two sources of evidence can be considered, however:

1. The numbers of breeding stock coming from the two sources.
2. The relative qualities of the two pig populations.

1. The Numbers of Breeding Stock Supplied

The figures for sales of breeding stock in recent years were shown in Table 5.3. Separate figures were given for nucleus and reserve nucleus (central test herds), multiplier herds and independant breeding company herds. These were aggregated to give greater reliability for extrapolation and since in practice it is inappropriate to differentiate between stock from the central test and the companies in terms of use by the commercial industry. If the numbers of breeding stock present in the commercial herds in 1977 coming from the two sources are estimated separately (by the same methods as used to estimate total presence in Chapter 5) it can be seen that the central test was still making a significant contribution. In terms of boars approximately 27% are estimated to have come from nucleus herds and their multipliers as opposed to 48% from the independent companies. For sows the picture is less clear. For crossbred gilts sold directly the figures are 3% and 21% respectively. Using the assumptions in Chapter 5 on the numbers of crossbred gilts bred in commercial herds from purchased purebred sows, the estimated contributions are 20% by the nucleus herds and 33% by the companies. If breeding stock produced by AI could be accurately counted and aportioned these would add to the significance of the central test's contribution. In Chapter 5, AI was estimated as supplying over 12% of commercial herd breeding stock in 1977.

2. The Qualities of Stock Available

Conclusions here can be drawn from the CPE tests run by the MLC. It was shown above that the average performance of stock from the two sources of improvement have been very similar (Table 4.4).

Thus the evidence suggests that the central test is still making a significant contribution to pig improvement in Great Britain.

Further, several of the independent companies still make some use of MLC facilities, including in some cases the central test. In the short term then, the removal of public investment in pig improvement would leave a gap which could not be filled immediately by the independent companies. In the longer term such investment could be left entirely to the private sector but it cannot be said whether or not this is desirable.

One argument may be that leaving improvement work solely to the independent breeding companies might lead to many of the smaller improvement herds currently relying on MLC schemes being unable to continue as effective nucleus herds. This further concentration of effort into a small number of herds may be seen as potentially hazardous for a number of reasons. On the other hand it may be argued that market forces would lead to the most efficient allocation of resources. One fear might be that in the absence of competition from national improvement programmes the breeding companies might begin to spend less on achieving improvement and more on advertising their stock. A simple protection against this would be the continuation of some monitoring test such as the CPE. In the absence of figures on the relative costs of improvement through private investment and through central schemes, argument here seems likely to be based solely on such matters of opinion as have been suggested, and seem unlikely to be resolved satisfactorily.

One possible area of danger deserves highlighting however. In Chapter 2 the appropriate discount rate was discussed. From the private breeders' point of view the social time preference rate is an inappropriate criteria for judging investments, the appropriate rate being the opportunity cost of capital to the breeder. Further, risk is far more significant to the independent company than to the nation as a whole so that earlier benefits become even more attractive. Thus in searching for optimum selection schemes the independent breeding companies would be encouraged to give greater weighting to short term benefits which may have less than optimal results for the nation as a whole. While the aims of pig improvement have been fairly consistent over the past fifteen years or so there is no guarantee that they will always be the same. Intensive selection in small populations, which may lead to faster progress in the short term, could lead to a lack of variation in the population available for future genetic change. Further consideration is given to such changes in the next section and the role of public investment is considered further.

9.4 FUTURE CHANGES IN BREEDING OBJECTIVES

The objectives of pig improvement in future years may well change. Past improvement might be thought of as having been towards a particular type of pig determined by current commercial requirements. Progress towards that goal has been a gradual process over a number of years. If that goal changes (and such a change could be quite sudden) progress towards that new goal can be expected to be a similarly slow process, perhaps made slower by a lack of variation left in the pig population due to past selection. Land (1981) gives examples of how goals may change and argues that the development of strains with divergent biological characteristics, as a supplement to existing policies, would increase genetic flexibility and could facilitate a faster genetic response to such change. Such investment would be very much in the nature of insurance: some investment would produce strains with characteristics that would be useful in situations that will never arise, while others produce benefits which justify the total expenditure. Land's proposals were put forward with the aim of encouraging some discussion on the topic. This seems a useful area for co-operation between economists and animal breeders in designing an optimum breeding strategy.

In considering possible sources of finances for such a scheme, it might be argued that there is little incentive for private organisations to undertake such investments. If pig improvement were left to the independent breeding companies they could not be expected to carry out such breeding for extreme biological types with little current commercial value. Such investment would be unattractive to private concerns being substantial for any single organisation (for many strains would have to be tried) having very uncertain benefits, probably a long time in the future, and having no way of protecting the benefits from the organisation's point of view. Thus, if such breeding programmes are to be undertaken, public funds would be required. Land goes further and argues that international schemes could be appropriate. Some international considerations are discussed in the next section.

9.5 INTERNATIONAL CONSIDERATIONS

The main study above has looked at the value of pig improvement solely in Great Britain. In Chapter 8 the value of international trade in breeding stock was considered but found to be small. The question might be asked, however, whether an alternative method of livestock improvement might have been to leave improvement work to other nations and rely solely on importing breeding stock from abroad. Certainly other countries have had their own improvement programmes. In looking at past improvement the question might be asked whether that investment was wasted. Land (1981) quotes examples from other species where after many years of selection the native breeds have been replaced by new breeds from abroad. With pigs it is not clear whether significant improvements could be made now by importing stock from abroad. Continuous comparisons of the kind reported by King et al (1975) would be required. Even if such superior stock were available and used it may be questioned whether this means that past improvement was totally wasted. Future benefits from past improvement would not be reaped but the improvement already achieved would still have had some impact in making the industry more efficient than it otherwise would have been. The argument introduced in Section 9.4 likening investment to insurance might also be extended here.

Of more significance, however, are possibilities for the future. Hill (1981) considers the possibility of relying on regularly importing improvement, although his comments mainly relate to cattle improvement. By relying on such a policy the level of investment could perhaps be reduced (how significant this reduction would be depending on the way in which improvements were imported). Against such a policy a number of arguments could be raised. Hill quotes two such arguments: where the risks of importing disease are considered too great, and where genotype x environment interactions between countries might mean that the benefits seen in one country are not obtainable in another. Certainly health restrictions have played a great part in restricting the movements of stock in and out of Great Britain in the past. No doubt more political arguments would also be raised with regards to the desirability of relying on other countries' efforts and foregoing the possibility of being leaders in the field. Thus again the case for relying on regular importation of improvement instead of maintaining domestic programmes is not clear-cut.

In terms of possible programmes as suggested in Section 9.4, arguments such as health dangers and genotype x environment interactions are less appropriate. Indeed it may be that the only way such schemes can be justified is where international co-operation is involved. With international programmes costs could be shared and the total benefits would be greater when counted over larger total animal populations.

Chapter 10

SUMMARY AND CONCLUSIONS

The purpose of this brief chapter is to summarise the main conclusions from the above study. This is perhaps best done with reference to the stated areas of interest from Chapter 1:

1. The value of pig improvement work in Great Britain
2. Implications for the future of pig improvement work
3. Wider issues relating to genetic improvement in general.

10.1 PAST IMPROVEMENT WORK

In Chapter 8 an overall NPV was calculated. The important reservation was noted that the extent to which the commercial industry has taken advantage of the genetic potential of the livestock available to it could not be certain given the approach adopted. Also, within the methods of appraisal a number of areas of doubt were highlighted which would make the estimate of NPV rather imprecise. Nonetheless past investment in pig improvement appeared to be worthwhile. Factors noted where further precision would be valuable, including factors relating to the achievement of the potential benefits at the commercial level, include:

1. The effects of selection on mature sow weight.
2. The value of different qualities of pigs under different feeding regimes and with different qualities of feed.
3. The degree to which the improvement claimed is of value to stock slaughtered at different weights.

4. The use to which artificial insemination is put in the commercial industry and the routes through which the remainder of the industry achieves progress.

The following issues have been discussed (in Chapter 9), though again more definite evidence would be valuable:

1. The distribution of the benefits claimed
2. The relative worth of public and private investment.

Regarding the former it was suggested that the major beneficiary of the progress achieved is the final consumer. The sort of detailed analysis necessary to produce more definite answers is beyond the scope of this thesis however. Regarding the latter the data available limits the conclusions that may be drawn though there is sufficient evidence to suggest that the MLC's central test is still making a valuable contribution to pig improvement.

10.2 FUTURE INVESTMENT

The future of pig improvement in Great Britain was discussed in Chapter 9. A simple extrapolation into the future was given to illustrate how further investment may be justified assuming the same rate of progress is maintained. It was pointed out that it is in considering future investment that the imprecision mentioned above could become more significant. Thus the need for a continuing check to be kept on the rate of progress is highlighted and efforts to quantify the issues above may be justified.

Some possible future developments were also discussed in Chapter 9. These included the possibility of future investment being left solely to the private sector, a possible alternative strategy for animal selection and the potential for international co-operation in animal breeding.

10.3 ISSUES OF MORE GENERAL INTEREST

While much of the study above is only of interest in relation to pig improvement in Britain, the study may be of wider interest both in illustrating one possible general approach and in highlighting some of the factors likely to be of significance in any future appraisal of investment in animal breeding. These include genetic lags, related responses in the performance of parent stock, the discount rate and the time period for analysis. Indeed one of the major values of such a retrospective study may be in raising questions which might not be obvious to appraisers at the planning stage. The discount rate has been a factor of particular interest to animal breeders recently and after discussion of this factor in Chapter 2 the effect of a wide range of rates was illustrated in Chapter 8, and the possible effects of the kind of rates quoted in some animal breeding papers was demonstrated.

A number of wider issues have been raised and areas for further research suggested, particularly in Chapter 9.

The scale of benefits are available for comparison with other studies. Indeed the scale of the net benefits quoted may be seen to prompt the question of what progress has been made or can be made with other species.

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