Queensland Journal of Agricultural and Animal Sciences, Vol. 39 (1), 81–92 (1982)
Published by Queensland Department of Primary Industries

Investment appraisal of central boar performance testing in Queensland

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Summary

The contribution of Queensland's boar performance testing scheme to the genetic improvement of the State's pigs was estimated from a model comprising three tiers: (1) the performance testing station, (2) the stud herds and (3) the commercial herds. Improvement disseminated from the station by the movement of sires between the tiers.

Monetary benefits to the pig industry and to the community as a whole were estimated using station, herd book and survey records. Costs and returns were discounted to present day values using real rates of interest in order to obtain the net present value of improvement from the testing programme.

With a discount rate of 5%, the time taken for returns to exceed costs to the pig industry was 7 years, while to the community it was 12 years. Net present values of improvement over a 20 year evaluation period were $\$2.2 \times 10^6$ and $\$6.2 \times 10^5$ for the industry and community respectively, even though gross returns were only 13% of those which would have been obtained had all stud sires been drawn from the station and all commercial sires drawn from the studs. This inefficiency is largely due to the absence of the same control over the use of tested boars as is exercised in European countries with central pig testing schemes.

1. INTRODUCTION

Most of Australia's pig population is derived from the Large White and Landrace breeds. The Queensland boar performance testing station evaluates the breeding values of stud boars of these breeds for economic traits. The best half are approved for use as sires, while the remainder are slaughtered. In common with similar schemes in North America, there is little control over the use of superior sires once returned to the herd of origin. This contrasts with most European schemes which exercise a higher degree of control over the use of superior stock identified through station testing, to ensure maximum genetic influence on their pig populations (Jonsson and Staun 1974). This has ensured a high level of cost effectiveness of these schemes of which the Swedish one is typical (Lindhé and Holmquist-Arbrandt 1976).

This study demonstrates the use of herd book registrations and survey data from the Queensland pig population to assess the cost effectiveness of a central testing scheme in which there is little control over the use of superior sires identified by the test. A model was constructed of the gene flow from stud herds to the testing station and from the testing station to the pigs sold for slaughter from stud and commercial herds. The strength of this flow was measured for the Queensland pig population and, from this, the contribution of the testing station to monetary returns from pig production was estimated and compared with the cost of running the testing station. Some inefficiencies in the process of passing improvement from the station to the industry were identified and their effects on returns evaluated.

2. THE MODEL

A model of the Queensland pig population is given in Figure 1. There are three levels, occupied by the testing station, the stud herds and the commercial herds. The arrows indicate the movement of young boars to and tested boars from the station, and the source of sire replacements used in the stud and commercial herds. Boars drawn from outside Queensland are shown as imports. The letters A to G represent the proportion of boar replacements in stud and commercial herds which move along these pathways. Thus $(A + B + C) = (D + E + F + G) = 1$. J represents the number of boars chosen from stud herds to be tested.

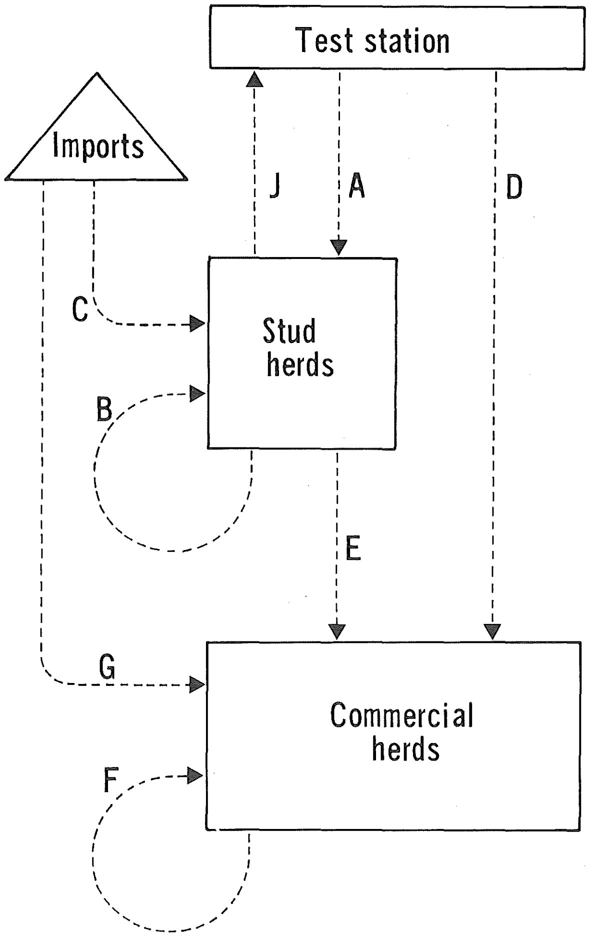

Figure 1. Model indicating sire replacement pathways of the Queensland pig population. *A*, *B* and *C* are the proportions of stud sires and *D*, *E*, *F* and *G* the proportions of commercial sires drawn from different sources. *J* is the number of young boars tested each year.

Definition of main symbols

$\triangle S$ — monetary improvement in stud herds

$\triangle M$ — monetary improvement in commercial herds

n — generation number

N — evaluation period in generations

I_1 — monetary superiority of tested boars used by stud herds

I_2 — monetary superiority of tested boars used by commercial studs

L — generation length in years

R — discount factor per generation

K_1 — number of slaughterings per generation in stud herds

K_2 — number of slaughterings per generation in commercial herds

NPV — net present value of improvement

Y — size of breeding population

T — number of breeding animals replaced each year

Stud herd improvement

Imports include both interstate and overseas boars and are assumed not to be improved by the station. If the average breeding value of tested boars entering stud herds is I_1 monetary units, the improvement due to the station in stud pig performance in generation 1 is:

$$\triangle S_1 = I_1 A/2$$

This equals the average breeding value in generation 2 of dams and of sires selected within stud herds without station testing and of young boars entering the station from which generation 2 sires will be selected. Improvement in generation 2 can then be given in terms of improvement in generation 1 as:

$$\triangle S_2 = \triangle S_1 (3 + A + B)/2$$

and in the 3rd and nth generations as:

$$\triangle S_3 = \triangle S_2 (1 + A + B)/2 + \triangle S_1$$
$$\triangle S_n = \triangle S_{n-1} (1 + A + B)/2 + \triangle S_1 \quad (1)$$

Commercial herd improvement

If the average superiority of tested boars entering commercial herds direct from the station is I_2 monetary units, the improvement due to the station in the performance of pigs from commercial herds in generation 1 is:

$$\triangle M_1 = I_2 D/2$$

This equals the average breeding value of dams and the sires of generation 2 selected within commercial herds.

The average breeding values of generation 1 progeny in stud herds and in station tested boars are $\triangle S_1$. This equals the breeding value of stud sires of generation 2 pigs used in commercial herds. The breeding values of sires drawn directly from the station also increase by $\triangle S_1$ in generation 2. Thus improvement due to station testing in generation 2 pigs in commercial herds can be expressed as:

$$\triangle M_2 = \triangle M_1 (3 + F)/2 + \triangle S_1 (D + E)/2$$

and in the 3rd and nth generations as:

$$\triangle M_3 = \triangle M_2 (1 + F)/2 + \triangle S_2 (D + E)/2 + M_1$$
$$\triangle M_n = \triangle M_{n-1} (1 + F)/2 + \triangle S_{n-1} (D + E)/2 + \triangle M_1 \quad (2)$$

Discounting

Monetary returns received at present will not be equivalent in value to the same returns received in the future. For this reason the net present value (NPV) of an investment must be determined by discounting all prospective net returns back to the present, using a predetermined rate of interest. The discounting technique has been described by numerous authors including Hill (1971), Levy and Sarnat (1978), and Peirson and Bird (1976).

The effect of inflation on costs and returns can be accounted for by using the following relationship of Levy and Sarnat (1978) and Smith (1978):

$$1 + r = (1 + q)\,(1 + h)^{-1} \tag{3}$$

where r is the real rate of interest, q is the annual nominal interest rate (for example bank overdraft rate), and h is the annual rate of change of consumer prices.

Evaluating improvement on a per generation rather than a yearly basis, the discount *rate* per generation (r') was determined from the relationship given by James (1972) as:

$$r' = (1 + r)^L - 1$$

and the discount *factor* per generation as:

$$R = (1 + r')^{-1}$$

Net present value

Returns from improvement are assumed to occur when pigs are slaughtered at u years of age, although some improvement, for instance feed savings, will be realized before slaughter. If K_1 and K_2 are the numbers of pigs slaughtered each generation by stud and commercial herds, returns from improvement in the nth generation discounted to present day values equal:

$$R^{(n+u/L)}\,[K_1\,\triangle S_n + K_2\,\triangle M_n]$$

The total discounted returns accumulated over a period of N generations is given by:

$$Tr = \sum_{n=0}^{N-u/L} R^{(n+u/L)}\,[K_1\,\triangle S_n + K_2\,\triangle M_n] \tag{4}$$

Assuming annual running costs remain constant at a, the equation given by Hill (1971) can be used to estimate total costs accumulated over N generations and discounted to the present as:

$$Tc = L.a\,[R - R^{(N+1)}]\,(1 - R)^{-1} + \text{(Establishment costs)} \tag{5}$$

The general formula used to determine the NPV of station testing is:

$$\text{NPV} = Tr - Tc \tag{6}$$

3. FITTING QUEENSLAND PARAMETERS

The Queensland testing station aims to improve two classes of characters of equal economic value: (1) carcass quality (lean %) and (2) economy of production (growth rate and food conversion efficiency). Improvement in economy traits results in savings in feed and housing, and benefits both the pig industry and community at large. It is difficult to define objectively benefits to the community from carcass improvement and it can be argued that, in the absence of exports of pig meat from Australia, the local consumer pays the producer for improved carcass quality and no net community benefits are gained. Thus benefits were calculated for

(1) the pig industry from improvement in both economy traits and carcass traits, and (2) the community from improvement in economy traits alone. The methods used to estimate Queensland parameters for the appraisal are described below.

Herd sizes and annual replacements

From the total number of breeding boars and sows in Queensland (Australian Bureau of Statistics, unpublished data), the number of boars and sows of Large White and Landrace descent was estimated from the proportional representation by registered pigs of the two breeds in the 1980 *Australian Stud Pig Herd Book*. The number of boars in use as sires at any one time in Queensland stud herds was determined from the equation:

$$Y_{1_b} = m\ (1 + w^{-1})^{-1}$$

where m is the number of different sires of all pigs registered in one year, and w is the average working life of boars (McPhee 1973).

The working lives of boars and sows (w) were calculated by examining the longevity of parents of a large sample of pigs registered in successive annual herd books. Average values obtained were 2.0 and 2.5 years for boars and sows, respectively.

From the ratio of breeding sows to boars found in herds sending young boars to the station for testing the number of sows in all Queensland stud herds (Y_{1_s}) was estimated as $8(Y_{1_b})$. This was subtracted from the ABS figures for all sows in the State to estimate the number of sows in commercial herds (Y_{2_s}). By difference between the ABS estimate of total boar numbers and Y_{1_b}, the number of breeding boars in commercial herds (Y_{2_b}) was also determined. These are given in Table 1.

Table 1. Estimated sizes of breeding population in stud and commercial herds (*Y*), and the annual breeder replacements required (*T*)

	Stud herds		Commercial herds	
Number of:	Y_1	T_1	Y_2	T_2
Sows (s)	1 504	602	42 886	17 154
Boars (b)	188	94	5 047	2 524

Knowing the number of breeding boars and sows in stud and commercial herds, annual replacements (T) were calculated from the general equation:

$$T = Yw^{-1}$$

Sow replacement numbers in stud and commercial herds T_{1_s} and T_{2_s} were determined by substituting Y_{1_s} and Y_{2_s} and w for breeding sows in the above equation. The total sire replacement needs of stud and commercial herds T_{1_b} and T_{2_b} were calculated similarly by substituting the appropriate values for boars. These estimates are given in Table 1.

Source of boar replacements

Registrations in the annual *Australian Stud Pig Herd Books* published from 1976 to 1980 inclusive were examined to estimate the proportions of sire replacements from the testing station (A), from the herds themselves (B), and from outside the State (C). Sires of registered pigs identified according to these three sources were, of course, born several years before their progeny were registered; for example boars tested in 1978–79 had their progeny registered in the 1980 herd book.

The numbers of station tested boars approved between 1973 and 1980 are plotted in Figure 2a and their proportional contributions to sire replacements in stud herds (A) in Figure 2b. To make the study current, the contribution of boars tested in 1979–80 to progeny registered in future herd books was predicted from the linear regression in earlier years of A on the number of boars tested and approved for use as sires x.

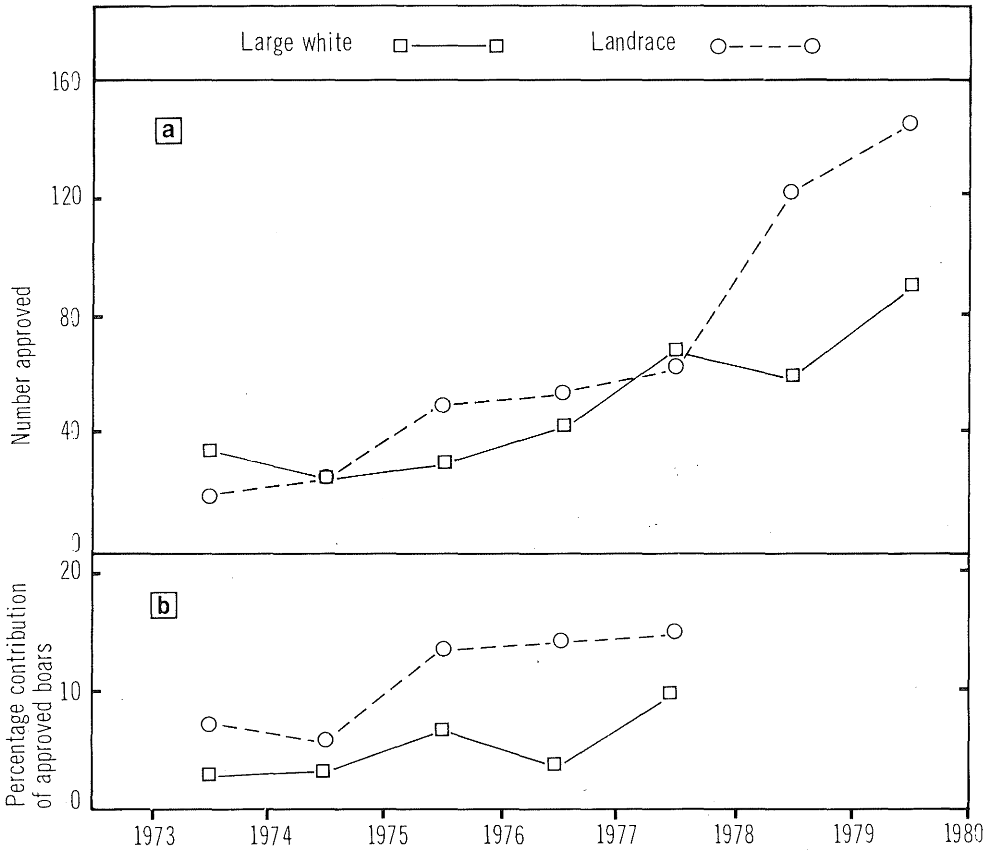

Figure 2. (a) Annual numbers of boars approved in the testing station. (b) Percentage contribution of tested boars to sires used in stud herds.

The pooled regression equation for Large White and Landrace was found to be:

$$100A = 0.094x + 0.2, \; (P<0.02)$$

Substituting the 1979–80 value of 241 for x gave a value of 0.23 for A.

The contribution of imports to stud sires showed no trend over the 5 sample years, so their current contribution to 1980 herd book registrations was used as an estimate of C. The home bred contribution to stud sires (B) was calculated from $1 - (A + C)$. The proportion of imported sires used in commercial herds (G) was assumed to be the same as in stud herds (C). The contribution of station tested boars to commercial herd sires (D) was estimated from the number of boars approved in the station but sold rather than used by the stud herds themselves. A survey was carried out to determine $D + E$, the proportion of sires used in commercial herds which were bred by stud herds (A. Todd, personal communication, 1980). The proportion of all commercial herd sires which were home bred (F) was calculated from $1 - (D + E + G)$. These estimates of the contributions of the various sources to sires used in stud and commercial herds are given in Table 2.

Table 2. Proportions of total sire replacements of stud and commercial herds drawn from the sources indicated in Figure 1

Source	Stud A	Stud B	Stud C	Commercial D	Commercial E	Commercial F	Commercial G
Proportions.........	0.23	0.61	0.16	0.09	0.31	0.44	0.16

Number of pigs slaughtered

The number of pigs slaughtered annually from each breeding sow (P) was estimated as 15.3 from statistics accumulated over the last 10 years (Queensland Department of Primary Industries 1980 and Australian Bureau of Statistics 1979). The product of P and Y_{1_s} and Y_{2_s} (Table 1) gave the total number of pigs slaughtered annually in stud and commercial herds, respectively. From these were subtracted all pigs used as breeder replacements and those boars which failed the station performance test.

The numbers of sire replacements moving along pathways in Figure 1 were calculated from the product of the total sire replacement needs for stud and commercial herds and the relative proportions of these given in Table 2. Neglecting culled breeding stock, slaughterings per generation from stud herds were then calculated as:

$$K_1 = L\ [Y_{1_s}P - T_{1_s} + T_{1_b}(A + C - B) - T_{2_b}E - J]$$

where J, the number of boars tested in 1979–80, was 482.

Similarly, the slaughterings from commercial herds were calculated as:

$$K_2 = L\ [Y_{2_s}P - T_{2_s} + T_{2_b}(D + E - F + G)]$$

Values obtained for K_1 and K_2 were 5×10^4 and 1.5×10^6, respectively.

Total discounted returns

Performance traits measured in the station are growth rate, food conversion ratio and backfat thickness. These are combined into a selection index (Cunningham 1972) reflecting the monetary worth of each animal's breeding value for economy of production and carcass traits. In constructing the index, local economic values were used, and genetic and phenotypic parameters taken from British testing station estimates (Meat and Livestock Commission 1972).

The average monetary superiority (I_1) of boars tested in the station in 1979–80 which were used as sires in stud herds (pathway A) was predicted from the regression of I_1 on the logarithm of the number of boars approved (x) using data from previous years. The rationale for using logarithms is contained in Smith (1969).

$$I_1 = 0.63 \log_e x - 1.26, \ (P < 0.05)$$

Substituting the 1979–80 value for x of 241 in this equation gave a value of \$2.25 for I_1.

The superiority of tested boars which went directly to commercial herds (pathway D) was calculated from:

$$I_2 = [I_{(1+2)}(AT_{1_b} + DT_{2_b}) - I_1AT_{1_b}]\ [DT_{2_b}]^{-1}$$

where $I_{(1+2)}$ is the average superiority of the 50% of all boars tested which are approved, and equals \$0.98. The value obtained for I_2, using appropriate parameters from Tables 1 and 2, was \$0.85. Using these values of I_1 and I_2 in equations 1, 2 and 4, total discounted returns from station testing were accumulated from 1 to 25 years.

Total discounted costs

The annual costs of operating the testing station (a) included those of labour, feed and fixed overheads. These were calculated to be $95,000 to the pig industry and $80,000 to the community, the difference between the two being the amount returned to the community by labour in the form of tax. Since the station has already been in operation for some 25 years, its cost of establishment was not included. Total discounted costs were calculated using equation 5 and, as was done for returns, these were accumulated for testing periods from 1 to 25 years.

Net present value of testing

Subtracting discounted costs from returns gave NPVs of station testing to the pig industry. These values were accumulated over periods of testing from 1 to 25 years and are plotted for discount rates of 2, 5 and 8% in Figure 3.

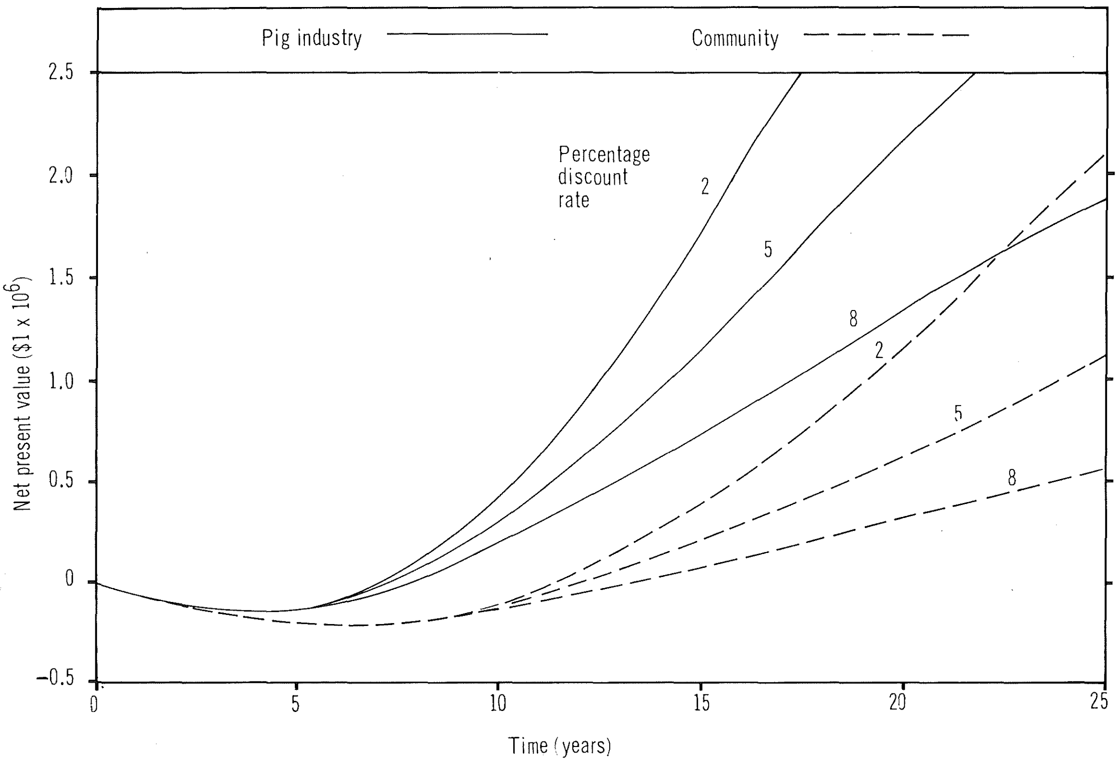

Figure 3. Net present value of the station's contribution to improvement in the pig industry and the community at three annual discount rates.

There is a delay of 7 to 8 years (payback period) before accumulated benefits to the pig industry overtake costs. At this point the benefits for the three discount rates diverge markedly. After 20 years of testing the accumulated benefits have NPVs of $\$4.2 \times 10^6$, $\$2.2 \times 10^6$ and $\$1.2 \times 10^6$ at discount rates of 2, 5 and 8%, respectively.

In calculating benefits to the community, costs are slightly lower but returns are halved since only improvements in economy of production but not carcass traits are received. The NPVs of testing to the community are also plotted in Figure 3. Compared with benefits to the pig industry, the benefits to the community have a slightly longer payback period of 11.5 to 13.5 years. Benefits accumulated over 20 years of testing are also lower at $\$1.1 \times 10^6$, $\$6.2 \times 10^5$ and $\$3.3 \times 10^5$ for 2, 5 and 8% discount rates, respectively.

Efficiency of station testing

Two main sources of inefficiency are evident in the process of improving the Queensland pig population by the testing station: (1) stud herds do not draw all of their sire replacements from the best boars identified in the station and (2) commercial herds do not draw all their sire replacements from stud herds. Assuming both these conditions were met, the station could be said to be operating with 100% efficiency and the NPV of returns to the pig industry calculated with a 5% discount rate would reach $\$1.1 \times 10^7$ after 15 years. At present the level of efficiency is only 13.2%.

If stud herds drew the same number of approved boars at present but selected only the best from the test station and importation from outside the State were discontinued, the efficiency of the station's contribution would be increased by a further 5%, to 18.2%. The additional improvement gained by increasing the proportion of tested sires in studs (A) and stud sires in commercial herds ($D + E$) is illustrated in Figure 4.

The striking feature of the efficiency curves in Figure 4 is their symmetry. The same increases in the proportion of stud boars drawn from the station (A) and in the proportion of commercial boars drawn from studs (E) result in improvements in efficiency which are about equal.

4. DISCUSSION

The results show that the Queensland boar performance testing station is cost effective despite its small size in relation to the total pig population. It gains much of its effectiveness through occupying a position at the top of a breeding pyramid where there is a generally downward movement of genes from stud to commercial herds.

Smith (1959) has shown that where the number of animals which can be performance tested each year is small relative to the number needed as breeder replacements, effort should be concentrated in a nucleus of herds upon which the bulk of the population depends for its supply of breeder replacements. In most European countries with central pig testing schemes, testing is concentrated in a small elite group of herds known to be of high genetic merit and to have a high genetic impact on the whole pig population. In Great Britain these herds are known as 'nucleus herds' (Meat and Livestock Commission 1970). In Queensland, stud Large White and Landrace herds are a well defined group of genetically influential herds, although a fairly large one relative to the size of the testing station which serves them.

In recent years there has been a growth of on-farm performance testing in Queensland (McPhee and Todd 1981). Compared with station testing, this has the potential for testing many more pigs for each one selected as a replacement breeder. However, it has so far been confined mainly to large commercial piggeries which tend not to spread the benefits to other herds through the sale of breeding stock. The stud herds generally have been slow to institute on-farm testing, particularly of boars. The chief inhibiting factor has been their small size which prevents them from forming sufficiently large performance test groups to be efficient. The testing station overcomes this deficiency by pooling the resources of a number of herds. Other advantages of station over farm testing were given by McPhee (1975) as greater accuracy and comprehensiveness of performance measurement and the utilization of the genetic variation existing between herds. A recent analysis has confirmed an earlier report (McPhee 1974)

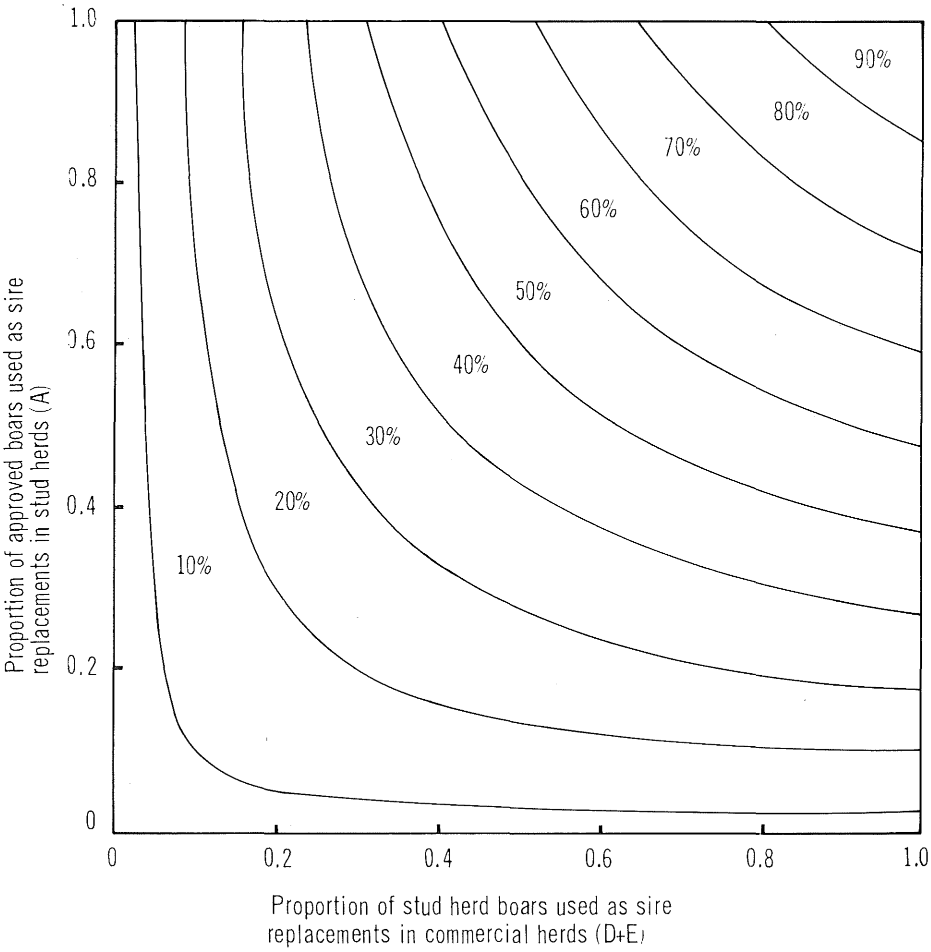

Figure 4. The percentage efficiency of the station's contribution to pig improvement as a function of the proportion of improved boars used in stud and commercial herds (evaluation period 15 years, discount rate 5% per annum).

that 10% of total genetic variation is in this form. This is not available to genetic improvement programmes carried out on the farm. Another useful role of station testing is in evaluating the worth of imports in comparison with a broad cross-section of local stock. This helps to temper uncritical enthusiasm usually displayed for breeding stock with an 'imported' prefix.

The efficiency analysis showed that best use was not being made of the station. One serious weakness was the direct movement of superior boars from the station to commercial herds (pathway D, Figure 1). In bypassing the stud herds, their role in multiplying the superior genes carried by these sires was missed. Changes in testing rules have been made to help overcome this inefficiency. Young boars sired by approved boars now have preference to testing space over those not sired by station tested boars. Another apparent inefficiency was the failure of commercial herds to draw all of their sire replacements from stud herds (pathway E, Figure 1). The consequences of this for genetic improvement would depend on the extent to which home bred sires in commercial herds were performance tested on the farm.

The model assumes no transfer of females between stud and commercial herds. The error arising from this assumption would be slight. Most commercial producers select female replacements from within their own herds. This is because pure bred females from studs lack hybrid vigour, and individual boars have a much greater genetic impact than individual sows.

In calculating the benefits of station testing, it was assumed that the pig industry gains from improvement in carcass quality. However, the industry may, in the long run, not be compensated for this improvement since standards of quality can easily be upgraded by abattoirs. This loss may be balanced by a hidden gain resulting from improved economy of production flowing on to the consumer in the form of lower prices and resulting in an improvement in the competitive position of pig meats in relation to other meats. This phenomenon has already been noted in Britain by Mitchell (1980). The pig industry may ultimately benefit through future expansion relative to other meat industries but, in the short term, benefits may be suppressed.

Because of the risks associated with the pig industry, it is desirable to evaluate returns from investment over a short time. This however is contradictory to the long term nature of animal breeding programmes. Hill (1971) and Hinks (1971) have shown that periods of at least 5 to 10 years may be necessary before costs can be recouped. Thus, in evaluating the worth of the station to the pig industry, it would be advisable to choose a moderate evaluation period, say 15 to 25 years, and a higher discount rate, say 5%, than is normally used to assess projects with little or no risk. In Australia, using current rates of nominal interest and inflation with equation 3, a value of 2% per year was found for the real discount rate. This compares with 3%, the value calculated for Britain by Smith (1978).

There are none of the above risks in passing the benefits of improved economy of production to the community. This means that lower discount rates and longer evaluation periods can be applied when assessing returns to the community. The results will still be conservative since they do not include possible benefits of indeterminate value from carcass improvement. For example, a reduction in fat deposition may permit higher levels of feeding and therefore increased growth rates, while the higher lean content of meat cuts may reduce the cost of wastage.

The question that arises from this study is whether similar stations should be set up elsewhere. The decision to invest in central testing will depend on comparisons with other forms of investment which may be competing for the funds available. The comparison is complicated since it will not only depend on NPV but also on the initial capital cost, possible risks, payback period and the potential for future improvements in the gene flow from the station to the commercial pig population, the main source of inefficiency in Queensland.

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(Received for publication 12 November 1981)

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50243—S. R. Hampson, Government Printer, Queensland