Investment appraisal in competitive markets

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The methods discussed previously, evaluate returns from a breeding program in terms of the effect of genetic change on profit of commercial production. For example, the effect of an increase in genetic value of milk yield on profit of cows on a dairy farm. Commercial breeding programs that operate in a competitive market, however, do not derive their income from increased profit of commercial production but from increased market share for their germplasm. Although in a perfect market, the market share that a company's germplasm is able to attain should be directly related to the profit which that germplasm is able to generate in commercial production, such conditions often do not exist.

8.7.1 Economic perspectives in competitive markets

Dairy cattle breeding is a clear example where there is intense global competition for germplasm from progeny-tested bulls and individual bulls are sold on the basis of their estimated breeding values in competition with other companies or countries (see Figure 8.4). In addition, there is competition for contracting bull dams and all competitors have access to semen from all progeny-tested sires for use as bull sires. Thus, in this situation, an AI firm's breeding program is not closed but is part of a single global breeding program, in which, at equilibrium, all AI firms improve at the same rate but with genetic lags, depending on the effectiveness of each firm's improvement program (see Figure 8.5). This also implies that program improvements will have less of an impact on returns than they would have in a closed system.

Based on these considerations, commercial breeding firms must look at breeding programs from a different perspective, as illustrated in Figure 8.6. Important components then are:

1) procurement of superior germplasm
2) product development
3) product marketing

For example, for a conventional dairy cattle progeny testing program for dairy cattle, procurement of superior germ plasm includes sourcing of bull dams and bull sires from the available global cow and bull populations for production of young bulls or, if bull calves have already been produced by individual producers, sourcing of bull calves. The product development phase involves the progeny-testing of these young bulls.

Figure 8.4. A Competitive Global AI Industry

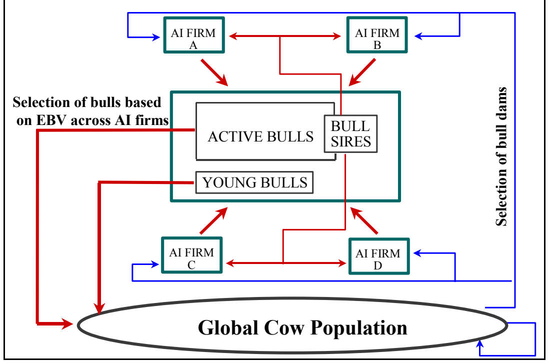


Figure 8.5. Impact of Improving Effectiveness of Selection by Firm A in a Competitive versus a Closed Market

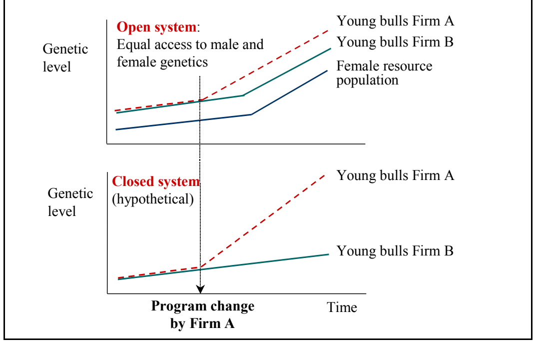


Figure 8.6. Breeding Company View of AI Progeny Testing Programs

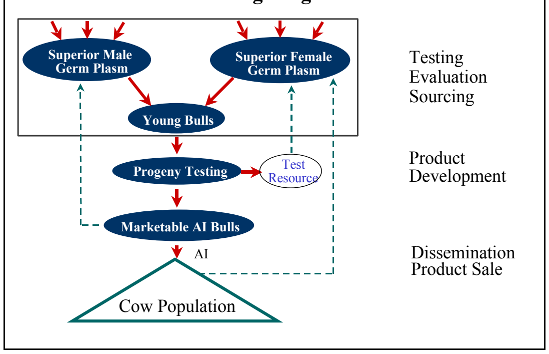
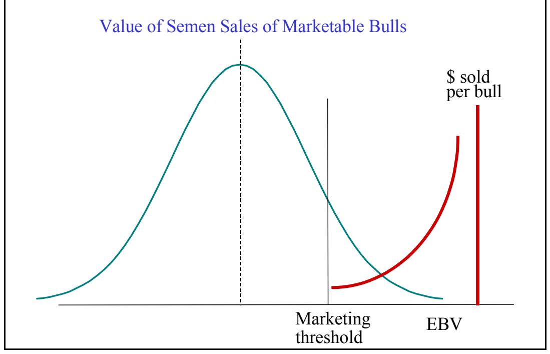


Figure 8.7. Effect of EBV on marketability and revenue

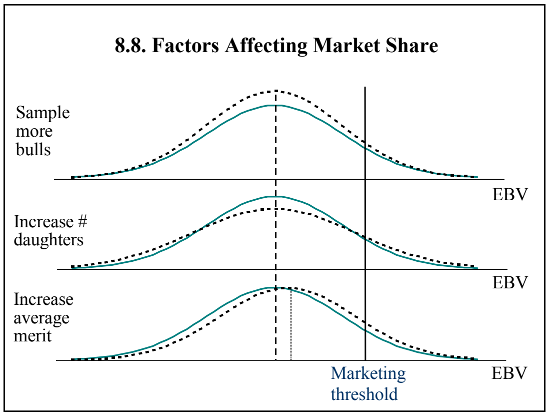


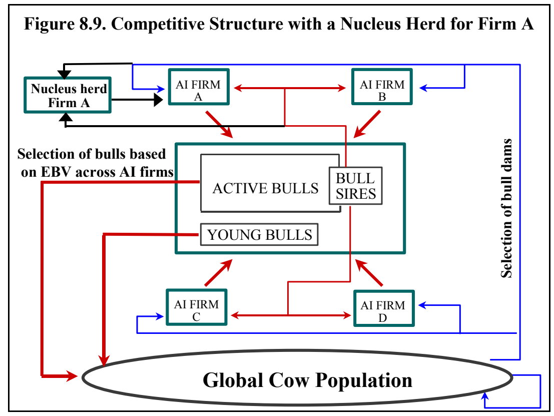
In such programs, returns are generated from the sale of germ plasm from marketable bulls. Only a limited number of bulls are required to breed the population, so that only those bulls above a certain threshold are likely to be saleable. A similar situation may also arise in some beef cattle and sheep breeding markets where animals (or their semen) are sold for breeding on the basis of their EBV. The situation is illustrated graphically in Figure 8.6. Only bulls above the threshold are saleable. For marketable bulls, there will also be non-linear relationship between the value of product sold and EBV of the bulls: more semen is sold from the top marketable bulls, plus it is sold at a higher price per unit.

In such a competitive market for breeding stock, there are three ways to increase market share in terms of share of value of germ plasm sold in the global market:

1) increase the size of the program
2) increase the mean of the germ plasm that is entered in the product development phase
3) increase the differentiation of germ plasm during the product development phase.

The impact of these three strategies on market share are illustrated in Figure 8.8 for a dairy cattle progeny testing program. For such a program, increasing the size of the program (1) amounts to increasing the number of bulls tested, increasing the mean of germ plasm entered the product development phase (2) amounts to increasing the mean genetic value of young bulls entered, and increasing differentiation of the germ plasm during product development (3) amounts to increasing progeny group size. The latter will increase the accuracy of EBV following progeny test, which increases the variance of EBV ($\sigma^2_{\hat{g}} = r^2\sigma^2_g$).





In this situation increasing the mean of the genetic value of procured germ plasm can be achieved in two ways:

a) increasing effectiveness of selection of superior germ plasm from the resource population
b) increasing genetic progress in the resource population

Objective a) can be achieved by applying the principles outlined in Chapter 3 by selecting the best sires and dams based on EBV from all available candidates, regardless of age or accuracy. With regard to objective b), in a conventional progeny testing program, an individual AI firm has limited impact on genetic gain in that population. In addition, all AI firms are in direct competition with each other for procurement of superior bull dams and thus source from the same population of selection candidates. Addition of a nucleus herd changes this situation. As illustrated in Figure 8.9 access to an AI firm's nucleus herd is restricted to that AI firm. This allows that firm to have some degree of protection of its female genetic resources. If selection procedures in the nucleus are more effective than in the general population, this will increase genetic gain and genetic lags, as illustrated in Figure 8.5.

The impact of alternative breeding programs and of nucleus herds on market share were studied by Dekkers and Shook (1990a,b) using a semi-stochastic simulation program (Dekkers and Shook 1990c). In this model, cows in the population were modeled deterministically as age groups with defined means and variances of breeding values. Sires appeared in the model as individuals (i.e. stochastically) with an EBV based on pedigree information and a daughter average performance. This process provided the actual number of sires achieving saleable status for each organization in each time period for a given replicate. Running the program many times allowed estimation of mean and variance of performance of a given selection strategy.

The impact of selection strategies on market share can, however, also be evaluated using a complete deterministic model. The deterministic model would model the mean and variance of true and estimated breeding values of each sex-age group. For bulls, means and variances would be modeled by AI firm. Then, assuming multivariate normality, determination of the number of marketable bulls provided by an AI firm would be obtained by determining the unique truncation point across distributions of EBV for all available age groups and AI firms such that the correct number of bulls is selected. Multiple truncation procedures described in Chapter 3 can be used for this purpose.

Let n_{ijt} be the number of marketable bulls from age group i of AI firm j at time t, which are selected from a Normal distribution with mean $\bar{\hat{g}}_{ijt}$ and variance $r^2_{ijt}\sigma^2_{g_{ijt}}$. Also, let $\phi(\hat{g},t)$ represent the functional relationship between EBV of a marketable bull and value of semen sold from that bull in a particular time period. Then, returns from semen sales from age group ij at time t, R_{ijt}, can be determined by integrating the relationship between EBV and value of sales over the truncated distribution: $R_{ijt} = n_{ijt} \int_{\hat{g}=\hat{g}_{M_t}}^{\infty} f(\hat{g} \mid \bar{\hat{g}}_{ijt}, r^2_{ijt}\sigma^2_{g_{ijt}})\, \phi(\hat{g},t)\; \partial\hat{g}$

where $\hat{g}_{M_t}$ is the marketing threshold for time t.

Returns per age group can be summed over age groups within AI firm to determine total returns at a given time t, discounted to determine the present value of those returns, and summed over time periods.

8.7.2 Example of economic optimization of progeny group size

Dekkers et al. (1996) used the semi-stochastic model of Dekkers and Shook (1990) to optimize progeny group size for a fixed testing capacity for young bulls in a competitive market (Figure 8.9). The principal question asked was, what is the combination of number of bulls sampled and number of daughters tested per bull that would maximize the net profits of an AI organization that is in competition with three other companies for sale of bulls into a market requiring 36 bulls, each selling 25,000 doses of semen per 6 mo. period? The base situation was each AI firm testing 60 bulls per annum, with 60 daughter records per bull. The performance of one organization, which varied its sampling program, was evaluated, while all other organizations maintained the original sampling policy. Selection for net economic merit with $h^2 = 0.25$ was assumed.

Semen prices were assigned to an individual bull, k, based on the following linear or quadratic function of EBV: $\phi(\hat{g}_k, t) = p_{min} + b_t(\hat{g}_k - \hat{g}_{M_t})^q$

where p_{min} is the semen price assigned to the lowest ranking marketable bull across A.I. firms in a given time period ($4), and $(\hat{g}_i - \hat{g}_{M_t})$ is the difference in EBV between the i^{th} marketable bull and the lowest ranking marketable bull in time t. Exponent q is equal to 1 and 2 for the linear and quadratic price functions. Coefficient b_t was determined for each time period such that the average semen price remained constant ($15).

For each A.I. firm, discounted gross returns from semen sales were computed per semi-annual cohort of young bulls by discounting and summing over time the semi-annual returns from semen sales for each marketable bull in the cohort: $R_{ij} = 25000 \sum_t \sum_{k\,\varepsilon B_{t,ij}} \phi(\hat{g}_{ijk}, t)\,(1+r)^{-(t-1)/2}$

where R_{ij} is the total discounted gross return from the cohort of bulls sampled by firm j and born in semi-annual period i, r is the annual discount rate (5%), t is a semi-annual period in which bulls from cohort ij are marketable, and $B_{t,ij}$ is the set of bulls from cohort ij that are marketable at time t, and. Factor 25000 represents the number of doses sold per marketable bull per half year.

Total discounted sampling costs per cohort (C) were computed as: $C = N(F + VD)$, where N is the number of bulls sampled, F is the fixed cost per bull sampled, which includes all costs for a young bull associated with purchase, housing, feeding, etc., D is progeny group size, and V is the variable cost per daughter record, which mainly consists of incentives to producers for use of young bull semen. Similar to returns, costs were discounted to the time of birth of the cohort of young bulls at 5% per year.

The model was run for twenty combinations of numbers of bulls sampled and progeny group size for AI firm A, keeping the program of the other three AI firms at the base level of 60 bulls sampled and 60 daughters per bull tested.

Summary data for number of bulls marketed and gross returns per cohort were then analysed using response surface methodology by fitting the following quadratic response surface to the twenty data points: $$Y(N_k, D_l) = \quad = b_1 N_k + b_2 N_k^2 + b_3 D_1 + b_4 D_1^2 + b_5 N_k D_1 + e_{k1}$$
where $Y(N_k, D_l)$ is the mean response for firm A when it samples N_k bulls per year with D_l progeny per bull.

Response surfaces for discounted net returns per cohort were obtained by subtracting $C = N(F+VD)$ from the response surface for gross returns or, equivalently, by subtracting F and V from parameter estimates for b_1 and b_5.

In many cases, the number of cows that is available to an A.I. firm for insemination with young bull semen is limited. Test capacity was defined in terms of the number of young bull daughters per annual cohort of bulls sampled by an A.I. firm: $T = ND$. Optimum utilization of a fixed test capacity in terms of number of bulls to sample versus progeny group size was investigated by reformulating the estimated response surface equations by substituting $N = T/D$:

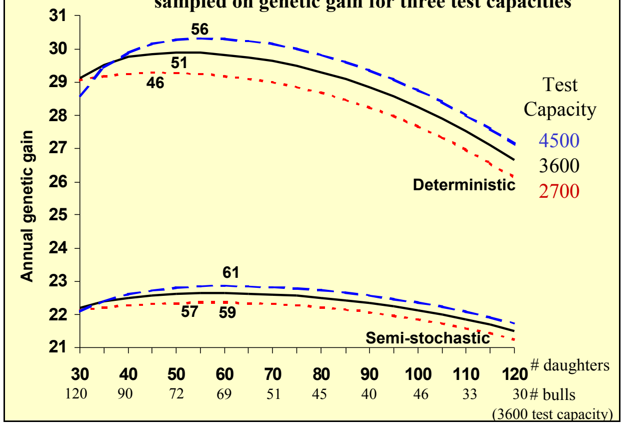
$$Y(D,T) = \mu + b_1 T/D + b_2 T^2/D^2 + b_3 D + b_4 D^2 + b_5 T$$

Optimum progeny group size for a given test capacity T was derived by maximizing $Y(D,T)$ with regard to D, which resulted in the following quartic polynomial for optimum progeny group size (D^*): $$2 b_4 D^{*4} + b_3 D^{*3} - b_1 T D^* - 2 b_2 T^2 = 0$$
with a shadow value for T of: $$\lambda_T = b_1 / D^* + 2 b_2 T / D^{*2} + b_5$$

Solutions for D^* were obtained by using Maple V (Maple V, 1994, Waterloo Maple Software, Waterloo, ON, Canada). Optima and shadow values for net returns per cohort were obtained by replacing estimated parameters b_1 and b_5 for gross returns by (b_1 - F) and (b_5 - V).

Figure 8.10 shows the effect of progeny group size and numbers of bulls sampled on genetic gain for fixed test capacities. To determine the effect on genetic gain, breeding programs were changed for all four AI firms. Genetic gain was also estimated using a deterministic model based on the asymptotic equations developed in Chapter 3 but ignoring the Bulmer effect.

Figure 8.10. Effect of progeny group size and number of bulls sampled on genetic gain for three test capacities



Increasing progeny group size (and decreasing number of bulls sampled) had a greater effect on deterministic predictions of genetic gain than on genetic gain predicted based on the semi-stochastic model; when progeny group size was greater than 50, the effect of reducing the number of bulls sampled on selection intensity outweighed increases in accuracy for deterministic predictions. This was less the case for semi-stochastic predictions. The reason is that relative increases in accuracy with progeny group size are larger when the effects of selection are accounted for (see Chapter 4).

For the deterministic method, optimum progeny group size was 46, 51, and 56 for test capacities of 2700, 3600, and 4500 young bull daughters (Figure 8.10). Optimum progeny group size was larger under the stochastic method (57, 59, and 61 daughters). For both methods, small to moderate deviations from optimum progeny group size had a small effect on genetic gain.

Figure 8.11 shows how market share, in terms of number of marketable bulls, depends on progeny group size and number of bulls sampled for a fixed test capacity. Progeny group size that resulted in the maximum number of marketable bulls increased with test capacity: optimum progeny group size was 22, 31, and 40 for test capacities of 2700, 3600, and 4500. For a given number of bulls sampled, differences between lines in figure 8.11 reflect the effect of progeny group size on market share through its effect on accuracy. As expected, the effect of progeny group size was smaller for larger progeny group sizes (left side of Figure 8.11).

Figure 8.12 shows the effect of progeny group size and number of bulls sampled on discounted net returns for a fixed test capacity of 3600 and a quadratic price function, for varying fixed costs per bull. For a fixed test capacity, total cost for young bull daughter incentives are equal to *TV* and unaffected by the number of bulls sampled and progeny group size. Incentive costs per daughter do, therefore, not affect the shape of the contour lines in Figure 8.12, nor the optimum progeny group size. Changing the number of bulls sampled does, however, affect total fixed costs. A fixed cost of $0 gives discounted gross returns. Increasing fixed cost per bull increased the optimum progeny group size (Figure 8.12). Curves were, however, relatively flat around the optimum. For typical fixed costs per bull in Canada of $30,000, optimum progeny group size was 102.

Figure 8.11. Market Share with Fixed Test Capacity

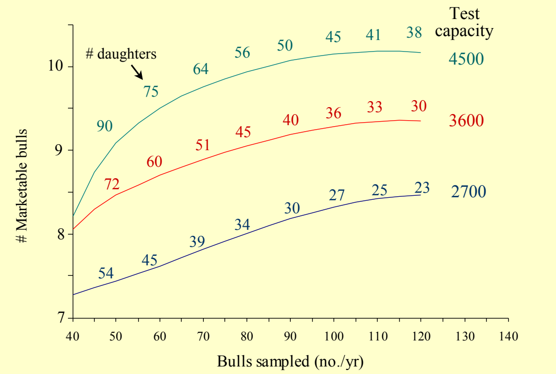
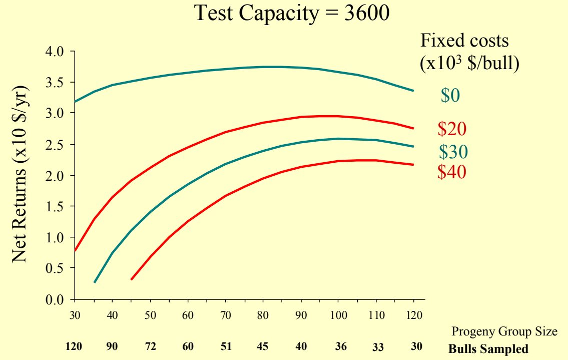


Figure 8.12. Maximizing Net Returns from Semen Sales

Test Capacity = 3600



Global optima for other cost scenarios and for the linear price function are in Table 8.9. The optimum number of bulls to sample was highly sensitive to the cost of sampling, but sampling cost had a limited effect on optimum progeny group size. Comparing optima for the linear and quadratic price function (Table 8.9) shows that price function had almost no effect on the optimum number of bulls to sample but optimum progeny group size was slightly lower for the linear price function.

Table 8.9. Optimal progeny group size for a fixed test capacity (from Dekkers et al. 1996)

	Test Capacity					
	2700		3600		4500	
	Fixed costs per bull ($x10^3$)					
Deviation from base[1]	\$20	\$30	\$20	\$30	\$20	\$30
	------------------------- Optimum progeny group size ------------------					
None	98	102	97	102	97	103
Linear price function	92	97	91	98	91	98
Population size +20%	96	100	95	100	95	100
Population size -20%	100	104	100	105	100	107
Semen price +20%	97	100	95	100	95	100
Semen price -20%	100	104	100	105	100	107
Interest 8%	100	104	99	104	100	106
One competitor at 100	99	102	99	103	99	105
	--Extra profit ($x10^4$ \$/yr) at optimum versus at 60 daughters/bull--					
None	49	66	49	73	56	86
Linear semen price	28	44	28	50	34	61
One competitor at	54	72	56	80	61	92
	------------------Shadow value of test capacity (\$/daughter)---------					
None	376	274	338	238	289	195
Linear semen price	397	287	352	246	305	207
Population size +20%	454	348	416	313	377	278
Population size -20%	259	161	229	134	200	109
Semen price +20%	495	389	448	344	398	300
Semen price -20%	259	161	229	134	200	109
Interest 8%	282	183	251	155	219	128
One competitor at 100	261	163	242	145	222	129

[1] In the base situation population size is 950,000 cows, semen price is based on a quadratic function of estimated breeding value, average semen price is \$15, interest rate is 5% per year, and the three competing AI firms sample 60 bulls with 60 daughters each.

Table 8.9 also shows the additional profit per annual cohort of bulls of sampling at the optimum instead of at 60 daughters per bull. Sampling at 102 daughters per bull instead of at 60 increased discounted net return by \$730,000 per annual cohort or by 38%. Reducing fixed costs to \$20,000 per bull reduced the optimum progeny group size by five daughters and also reduced the economic benefit of moving to the optimum scheme.

Optimum progeny group size was little affected by test capacity (Table 8.9). However, the economic benefit of optimising progeny group size was greater for larger test capacity, at least in absolute terms. Table 8.9 also shows the shadow value of test capacity, which is equal to the extra profit that can be expected when increasing test capacity by one daughter under an optimum design. Shadow values do not incorporate incentive costs (V) but represent the maximum incentives that could be paid to increase test capacity by one daughter without reducing profit. Shadow values were lower for larger test capacities and for larger fixed costs per bull. Shadow values were, however, greater than the $180 incentive that was on average provided to producers by Canadian A.I. organizations. Table 8.9 also shows that the optimum was little affected by population size, semen price, or interest rate.

Market share of an A.I. firm depends not only on the firm's own breeding program but also on the breeding program of its competitors. Previous results were for situations in which competitors conducted the base breeding program of sampling 60 bulls with a progeny group size of 60. Optimum progeny group size was, however, little affected when one of the competitors sampled bulls with a progeny group size of 100 daughters instead of 60 (Table 8.9). Although profit was significantly lower when one competitor sampled at 100 daughters per bull instead of at 60, the economic benefit to firm A of sampling at the optimum progeny group size instead of at 60 daughters per bull was little affected by the breeding program of its competitor. This represents the opportunity cost of not changing to the optimum of 100 progeny per bull.