Customised selection indices

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Abstract

The relative efficiency of customising selection indices according to relative economic values was investigated for a cattle scenario for which the breeding objective consisted of a combination of a production and fitness trait. The extra response from using customised indices rather than a single national index was small for typical dairy cattle parameters. For beef cattle, customised indices may be more important. The impact of customised selection indices on genetic progress may be through a better adoption of selection indices in general.

1. Introduction

The economic performance of animals can differ across environments if relative economic values of trait improvements (economic weights) are different in different environments, if traits are genetically not the same across environments, or in a combination of both. In this study we will deal only with the first case, where genotype by environment (GxE) interactions occur because of different economic weights in different environments.

Farmers could end up choosing different bulls if GxE interactions occur. However, in most national and international (dairy) cattle programmes, A.I. companies tend to breed bulls for the average environment, and they do not create sublines which are suited to specific environments throughout the country/world. An economic appraisal of sublining was given by Smith (1985), but is beyond the scope of this study.

Given the assumption of an average breeding goal for which the A.I. companies breed bulls, is there any benefit for farmers to choose bulls based on customised selection indices? This is particularly relevant for secondary traits, because it has been argued that the economic weights for such traits often depends on the mean level of the individual herd, so that the trait may be important for some farmers, but not for others. An implicit assumption is that profit is a non-linear function of these traits.

The aim of this study is to investigate the short term benefits of customising a total merit index for a fitness trait.

2. Customising a total merit index

2.1 Assumption and notation

We assume that the breeding goal (H) for a herd consists of breeding values for a production trait (A_p) and a fitness trait (A_f). The heritabilities of these two traits and the genetic correlation between them are assumed to be the same across all herds. The economic weight for the production trait, v_p, is also assumed to be constant, while the economic weight for the fitness trait, v_i, is specific to herd i. Nationally, multivariate EBVs are calculated for the production and the fitness trait, and a farmer can rank the bulls according to an average breeding goal, or according to his own breeding objective. Assume that the EBVs for the production and fitness trait are calculated with reliabilities of R_p and R_f, respectively, and that both traits have been standardised to have a phenotypic standard deviation of unity. Economic weights are expressed accordingly.

For herd i,

$$H_i = v_pA_p + v_iA_f$$

$$E(v_i) = v_f,$$

where the Expectation is over the population of herds in the country. Progeny tested bulls can be ranked according to an average (national) index, I,

$$I = v_pEBV_p + v_fEBV_f$$

Alternatively, a customised index can be used,

$$I_i = v_pEBV_p + v_iEBV_f$$

2.2 Response to a single round of selection when A_p and A_f are uncorrelated

The response in herd i (ΔH_i) through a single round of selection using the national index is, in standardised selection differential units,

$$\Delta H_i|I = r(H_i,I)\ \sigma(H_i) = cov(H_i,I)/\sigma(I)$$

$$= [(v_p^2R_ph_p^2) + (v_fv_i\ R_f\ h_f^2\ )]\ /\ [(v_p^2R_ph_p^2) + (v_f^2R_fh_f^2)]^{½}. \qquad [1]$$

The response in herd i given the national index is linear in the economic weight v_i, so because $E(v_i) = v_f$, the average expected progress in all herds is,

$$E(\Delta H_i|I) = [(v_p^2R_ph_p^2) + (v_f^2R_fh_f^2)]^{½} = \sigma(I) = \Delta H_{average} \qquad [2]$$

which is the same response as would be obtained if all economic values were the same across herds.

The response from using the customised index is,

$$\Delta H_i|I_i = \sigma(I_i)$$

$$= [(v_p^2R_ph_p^2) + (v_i^2R_fh_f^2)]^{½}. \qquad [3]$$

Using a second order Taylor series around $v_f = E(v_i)$ gives, after some tedious algebra,

$$E(\Delta H_i|I_i) \approx \Delta H_{average}[1 + ½CV^2c_fc_p/(c_f + c_p)^2]$$

$$= \Delta H_{custom} \qquad [4]$$

with

CV = Coefficient of variation of v_i
= $\sigma(v_i)\ /\ v_f$
c_f = $v_f^2R_fh_f^2$
c_p = $v_p^2R_ph_p^2$.

If $c_f << c_p$, or if $CV(v_i)=0$, the response reduces to the average response.

2.3 Response to single round of selection when A_p and A_f are correlated

In many situations, the production and fitness traits will be negatively (i.e. unfavourably) correlated. We assume that the EBVs for both traits are calculated from progeny averages on both traits, and that the traits are not measured on the same progeny (i.e., there is no environmental correlation between the EBVs). The latter assumption was made to make equations independent of environmental correlations. Then, if $\overline{Y}_I$ is the progeny average for trait i (production or fitness), deviated from the overall mean, and using standard selection index theory,

$$EBV_1 = 2b_1\overline{Y}_1 + 2b_2\overline{Y}_2$$

$$b_1 = R_1(1 - r_g^2R_2)\ /\ (1 - r_g^2\ R_1R_2)$$

$$b_2 = r_g\ (h_1/h_2)R_2\ (1 - R_1)\ /\ (1 - r_g^2\ R_1R_2)$$

with r_g the genetic correlation between the production and fitness trait.

Using the above expressions, it can be shown that,

$$E(\Delta H_i|I) = [(v_p^2R_ph_p^2) + (v_f^2R_fh_f^2) +$$

$$2v_f v_p \mathrm{cov}(EBV)\ ]^{1/2}$$

$$= \sigma(I) = \Delta H_{average} \quad [5]$$

and

$$E(\Delta H_i | I_i) \approx \Delta H_{average}\{1 + \tfrac{1}{2}CV^2[c_p c_f - v_p^2 v_f^2 \mathrm{cov}^2(EBV)] / [c_p + c_f + 2v_p v_f \mathrm{cov}(EBV)]^2\}$$

$$= \Delta H_{custom} \quad [6]$$

and cov(EBV) is the covariance between EBV_p and EBV_f, which is calculated from the EBV index weights and the heritabilities and genetic correlation between the traits,

$$\mathrm{cov}(EBV) = \mathrm{cov}(EBV_p, EBV_f)$$

$$= b_{p1} b_{f2} h_p^2 / R_p + b_{p2} b_{f1} h_f^2 / R_f + r_g h_p h_f (b_{p1} b_{f1} + b_{p2} b_{f2})$$

with b_{p1} and b_{p2} the weights for $\overline{Y}_p$ and $\overline{Y}_f$ in the EBV calculation for the production trait, and b_{f1} and b_{f2} the weights for $\overline{Y}_f$ and $\overline{Y}_p$ in the EBV calculation for the fitness trait. Note that for $r_g = 0$, and therefore $b_{p2} = b_{f2} = \mathrm{cov}(EBV) = 0$, Equation [6] reduces to Equation [4], as expected.

2.4 Examples

In Tables 1 and 2 we show the expected single generation gain to be made from customisation for a range of values for CV (0.20, 0.50, 1.00), h_f^2 (0.05, 0.10, 0.20), and v_p:v_f (2:1, 1:1, in genetic standard deviation units). We also show the extra gain to be made from including the fitness trait in the national index relative to a national index which is just selection on production ($I = v_p EBV_p$). For those calculations we still assume a multivariate EBV, i.e. even though the fitness trait is not included in the (national) index, the data on the fitness trait is used to calculate the EBV for production.

Tables 1 and 2 show that unless the fitness trait has a relatively large economic weight, or a large coefficient of variation, little extra gain is to be expected from customisation. In nearly all cases the inclusion of the fitness trait in the index had greater impact than customisation once the fitness trait is used in the selection index. In a typical dairy cattle example, with v_p:$v_f \approx 2$:1 in genetic sd units, and $h_f^2 \approx 0.05$, the maximum gain for realistic values of CV(v_i) of, say, ≤ 0.5, is about 3%. However, the gain for individual farmers with extreme economic weights for the fitness trait may be substantial.

2.5 Verification of prediction equations

Predictions were checked using simulation, using either a normal, uniform, or exponential distribution for v_i. Both for the normal and uniform distribution, predictions agreed well with results from simulation. However, predictions were 30-50% too high if v_i was exponentially distributed.

3. Discussion

3.1 Selectabull

In Australia, a customised selection index computer program for the dairy industry (called Selectabull) was released in 1995 (Bowman et al, 1996). The program customises economic weights for milk production traits, and milking speed, temperament, survival, and mature body weight, using farm specific inputs, and ranks bulls based on the customised selection index. Bowman et al (1996) calculated customised indices for four very different types of dairy farms (representing geographical areas in Australia) and ranked available dairy bulls for each of the four environments. They found that correlation among pairs of selection indices was ≥0.95, and that at least 7 of the top 10 bulls were shared by pairs of indices. This highlights a general phenomenon in dairy cattle breeding, i.e. milk production is by far the most important trait in the objective, and including other traits in the objective has a marginal influence on which bulls to select.

3.2 Beef cattle

Selection indices in beef cattle are less likely to be dominated by a single group of highly correlated traits (e.g., Barwick et al., 1994) and so the advantages from customising indices might be slightly larger for beef cattle situations than dairy situations. Barwick et al. (1994) show calving ease as an example of a trait where the economic value depends on the incidence of difficult calvings in the herd. In crossbreeding situations, these incidences are likely to vary considerably because of the well known differences in calving ease across breeds of dam. When an optimal range exists for a carcase trait such as fatness, economic weights in a sire breed can be reversed in sign according to the breed of dam (Amer et al.,1993). Economic weights for most reproductive traits in beef breeding herds depend on the values for key herd reproductive variables (Amer, et al., 1996). Differences in herd means which bring about differences in economic weights across farms reflect optimal management under contrasting environmental circumstances. It is therefore not appropriate to assume that these differences will disappear in the long run due to improved management.

3.3 Implications

Customisation of selection indices in itself may not lead to much extra genetic progress. However, if the impact of customisation is to gain acceptance in the industry to the use of selection indices in general, this may indirectly lead to larger profits. This is particularly the case if farmers or breeders would otherwise 'switch off' and use their own (usually inferior) methods of bull selection (Bowman et al, 1996).

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Table 1. Extra gain (%) from customisation relative to gain from using a national index. $GAIN_f$ is the extra gain (%) from including the fitness trait in the national index relative to gain from using a national index with only production. Note that economic weights are in *genetic* standard deviation units. r_g=0, h_p^2=0.40, n=50.

	$v_p/v_f = 2$				$v_p/v_f = 1$			
	CV(v_i)			$GAIN_f$	CV(v_i)			$GAIN_f$
	0.20	0.50	1.00		0.20	0.50	1.00	
h_f^2								
0.05	0.2	1.2	4.6	5.6	0.4	2.7	10.8	20.7
0.10	0.2	1.5	6.1	8.0	0.5	3.0	12.0	29.0
0.20	0.3	1.8	7.3	10.2	0.5	3.1	12.4	36.2

Table 2. Extra gain (%) from customisation relative to gain from using a national index. $GAIN_f$ is the extra gain (%) from including the fitness trait in the national index relative to gain from using a national index with only production. Note that economic weights are in *genetic* standard deviation units. r_g=-0.3, h_p^2=0.40, n=50.

	$v_p/v_f = 2$				$v_p/v_f = 1$			
	CV(v_i)			$GAIN_f$	CV(v_i)			$GAIN_f$
	0.20	0.50	1.00		0.20	0.50	1.00	
h_f^2								
0.05	0.3	1.9	7.5	6.7	1.1	6.7	26.8	35.7
0.10	0.4	2.5	10.1	9.8	1.1	6.8	27.4	50.6
0.20	0.5	3.0	12.1	12.7	1.1	6.6	26.6	64.4