Economic weights for fertility and reproduction traits relative to other traits and effects of including functional traits into a total merit index

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Abstract

In breeding objectives traits should be included according to their economic importance. Economic weights were estimated with a herd model for production traits and functional traits under the assumption of a quota for the sum of fat and protein yields. For Simmental the economic weights per genetic standard deviation were ATS 345.- for fat yield, ATS 396.- for protein yield, ATS 155.- for daily gain, ATS 155.- for dressing percentage, ATS 58.- for EUROP carcass grading, ATS 306.- for longevity, ATS 100.- for conception rate, ATS 24.- for calving ease, ATS 55.- for stillbirth, ATS 40.- for persistency and ATS 200.- for mastitis resistance.
All these traits were included in the aggregate genotype. For the construction of a model for the calculation of a total merit index, estimated breeding values were used as entries to a selection index procedure. The index weights (b-values) were estimated according the reliabilities of the estimated breeding values and were therefore different from animal to animal.
The results indicated breeding in accordance to a total merit index will result in a monetary selection response more than 10 % higher than by use of an index without the functional traits.

1. Introduction

Under quota conditions and decreasing milk prices functional traits like reproduction traits, which increase efficiency not by higher output of products but by reduced costs of input (Groen et al., 1996) might have a bigger impact on the profit of dairy farmers and should therefore be included in breeding programmes. Fewson and Niebel (1986) showed that including functional traits in breeding programmes will have a major impact on the expected selection response of the functional traits and will result in only small losses of the expected selection response of the production traits. Apart from economic reasons for including functional traits in the breeding programmes there are several non economical reasons, for example ethical reasons and consumer concern, which become more and more important (Dempfle, 1992, Groen et al., 1996).

The optimal definition of the breeding objective is discussed extensively in the literature. After dealing with special aspects of defining a breeding objective Fewson (1993) gave a general definition: "Develop vital animals which will ensure that profit is as high as possible under future commercial conditions of production". Such a breeding goal inevitably implies the inclusion of several traits in an aggregate genotype, and index selection provides a way of combining the traits in an optimal way (Hazel and Lush, 1943).

Philipsson et al. (1994) gave a survey about including different groups of traits in a total merit index for bulls in various countries. The authors discussed the lack of interest in inclusion of functional traits and pointed out the following reasons: selection indexes are not worked out, sire evaluations are not available at all and low heritability without estimates of the real amount of additive genetic variation. A survey of the currently (i.e., 1996) used selection indexes in various countries is given in Miesenberger (1997). In Austria, estimated breeding values are currently published for the following set of functional traits: persistency, longevity, fertility and calving ease (both paternal and maternal). Breeding values for somatic cell score and stillbirth will be published the first time in February 1998.

For establishing a total merit index (TMI) after Hazel (1943) the relative economic weights of the traits considered in the aggregate genotype must be known. Groen et al. (1996) discussed in their report of an EAAP-working group the methodology in deriving economic weights and presented a summary of recent literature on economic values. Comparing economic values for the same traits from different studies is not that easy because of different trait definitions for the same characteristics, different methodology, different assumptions and different traits considered in the index. Before the estimation of the according economic weights, knowledge about the traits considered in the aggregate genotype is important because of the possibility of double counting (Dempfle, 1992).

In this study absolute and relative economic weights, estimated with a herd model under an assumed quota on the sum of fat and protein yields will be given for the dual purpose Simmental population in Austria. Additionally, effects on the expected selection response for the various traits, which are combined in a TMI will be presented. The following traits were considered: carrier, fat yield, protein yield, longevity, fertility, calving ease, stillbirth, persistency and mastitis resistance for cows and daily gain, dressing percentage, EUROP-grading score for fattening bulls.

2. Model, methods and assumptions

In this paper a short description of the model and method for the estimation of the economic weights and for the calculation of a TMI will be given. The most important assumptions are given in this chapter. For a more detailed description see Miesenberger (1997).

2. 1. Estimation of the economic weights

2.1.1. Description of the herd model

A herd including milk production, bull fattening and heifer rearing was simulated in a steady state over an infinite planning term. All the results were expressed per cow place and year. Reinsch (1993), who estimated economic values by the use of markov chains showed that in case of an infinte planning term the results per cow place and year do not depend on discount rate and the initial state of the herd.

A computer program developed by Amer et al. (1994) was adapted for the calculation of economic values for the various traits. The proportion (P) of cows in the herd with lactation number j depended on the probabilities p_k of survival from time k to k+1. p_k depended on the percentages of cows per lactation j culled for infertility (inf_j), for involuntary (inv_j) and voluntary reasons (vol_j). It was assumed that the herd distribution stays constant over time.

$$P_j = \prod_{k=0}^{j} p_k \Big/ \sum_{i=1}^{n} \prod_{k=0}^{i} p_k \qquad (1)$$

n = maximum number of lactations

As an example, the proportion of the cows culled in lactation j for infertility $P_{inf,j}$ was calculated by $P_{inf,j} = P_j * inf_j$. In the same way the proportion of the cows culled voluntarily $P_{vol,j}$ or culled involuntarily $P_{inv,j}$ were computed. In this way the expectations of n times 4 cow classes were calculated.

The average milk production of the 2nd and further lactations was calculated by applying multiplication factors describing the relative production level in different lactations due to the ageing process. All the costs and revenues were calculated per day. The function of Wood (1967) was used to estimate the daily milk, fat, and protein yields. Maximum daily dry matter intake was calculated by the formula of Gruber et al. (1990). Daily energy and protein requirements for maintenance and production were calculated according to the equations described in Geh (1986). Differences in requirements because of live weight changes were taken into account. A linear planning algorithm was used to select a least cost ration which met the protein and energy requirements while respecting the constraints.

The daily results were summarized over a calving interval or until culling depending on the fate (=cow class) of a cow. For each cow class all the results per cow class were multiplied by the according relative proportion. The sum gave the results per cow place. Profit from bull-fattening and the heifers sold were added to the profit per cow place according their occurence per calving.

2.1.2. Calculation of the economic weights

The economic value of a trait was computed by calculating herd profit per year before and after a genetic change. The difference in herd profits was then divided by the number of cows per herd times change in production for one cow. All costs were treated as variable. The size of the farm was only constrained by the considered quota. If the assumed genetic change of the various traits had an effect on the traits under quota, then downward scaling of the farm was allowed.

2.1.3. Assumptions

The economic weights, which are presented in this study were calculated under the assumption of a quota on the sum of fat and protein yield. One reason for this assumption is the discussion about the possibility of the standardisation of the fluid milk for protein, another reason is that more than 20 % of the produced milk fat and milk protein cannot be sold without price support under the current market conditions in the EU.

With respect to the Simmental population the following reference situation was defined. The average milk yield per cow place and year was 5321 kg milk, 223 kg fat and 180 kg protein. The age structure of the herd modelled (Table 1) approximated the situation in the present Austrian Simmental population assuming a maximum of 9 lactations per cow.
The average cycle length of 348 days depended on the cow class distribution, culling days and the assumed calving interval of 391 days as a result of (in)fertility and management. Average length of productive life was 3.35 years. For a comparison see Reinsch (1993) who found a very similar reference situation in German Simmental.
The percentage of infertility culling depended on the conception rate (CR) and the maximum number of inseminations which resulted in infertility culling. Assumed average CR per lactation and insemination were taken from the Simmental population of Lower Austria. CR was defined and calculated as the percentage of calvings per insemination.
Figures about the fertility situation in the Simmental population of Lower Austria are given in Table 2.

Table 1. Proportions (in %) of cow classes by lactation number and fate for the reference herd

	Lactation (j)								
	1	2	3	4	5	6	7	8	9
involuntary ($P_{inv,j}$)	3.4	2.7	2.2	1.8	2.2	1.6	1.2	1.0	1.6
infertility ($P_{inf,j}$)	1.0	0.8	0.5	0.5	0.5	0.3	0.2	0.2	0.0
voluntary ($P_{vol,j}$)	3.1	1.9	1.1	0.6	0.0	0.0	0.0	0.0	0.0
survivors	20.9	15.5	11.7	8.8	6.1	4.2	2.8	1.6	0.0
total (P_j)	28.4	20.9	15.5	11.7	8.8	6.1	4.2	2.8	1.6
Population mean	28.5	20.8	15.2	11.4	8.6	5.9	4.0	2.6	*3.0

* ≥ 9th lactation

Table 2. Figures about the fertility situation in the Simmental population of Lower Austria

parity	number of animals	RZ (days)	NRR-90 (%)	Successful insemination 1 CR	1 VZ	2 CR	2 VZ	3 CR	3 VZ	4 CR	4 VZ
heifer	47736	-	78	74	-	75	47	76	92	79	130
1.	39874	81	71	60	-	61	49	56	91	51	130
2.	32245	76	71	61	-	60	47	55	87	46	131
3.	25849	76	70	61	-	59	46	54	90	50	129
4.	20453	76	69	60	-	58	45	52	89	49	122
5.	15711	76	68	58	-	57	44	53	87	45	123
6.	11711	77	66	57	-	56	45	54	87	45	122
7.	8361	74	65	54	-	53	45	51	86	44	122
8.	5542	74	64	53	-	52	44	48	83	47	117

RZ = time between calving and the first insemination, NRR-90 = non-return-rate-90, CR = conception rate, VZ = average time between the first and the successful insemination

Some of the prices considered are given in Table 3. Most of the prices and costs in the basis situation were average prices in Austria in 1996. More details are given in Miesenberger (1997).

Table 3. Some prices and costs

returns	in ATS
milk carrier	0.50 / kg
milk fat	46.31 / kg
milk protein	57.75 / kg
bulls (carcass weight)	41.63 / kg
cow (carcass weight)	30.00 / kg
surplus heifer	19000.-

2.2. Estimation of the total merit index (TMI)

2.2.1. Model and method

In the TMI in Austria, the traits described in Table 4 are incorporated. In case of mastitis resistance the correlated trait somatic cell score will be included in the index (but not in the aggregate genotype). In addition to the TMI, subindices for groups of traits are calculated. Milk, fat and protein yields are combined in a ”Milk value”, daily gain, carcass percentage and EUROP-grading score give the "Beef value" and the combination of functional traits results in a "Fitness value". The TMI and the three subindices will first be published in February 1998.

The TMI is calculated using estimated single trait breeding values (EBV) and their approximated reliabilites. Individual index weights (b-values) are calculated for each individual based on the reliabilities of EBVs. The method is approximate as it does not correctly account for individual relationships.

2.2.2. Assumptions

The genetic correlations in Table 4, which are used by the index calculations were taken from the literature. A literature review is given in Miesenberger (1997).

Table 4. Genetic standard deviation (s_A), genetic correlations between the traits in the aggregate genotype (including somatic cell score) and reliablities assumed for the various individuals

	trait	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Carrier	1.00															
2	Fat	0.80	1.00														
3	Protein	0.90	0.85	1.00													
4	Dg	0.15	0.15	0.15	1.00												
5	Europ	-0.05	-0.05	-0.05	0.05	1.00											
6	Dp	-0.15	-0.15	-0.15	-0.05	0.50	1.00										
7	Long.	-0.10	-0.10	-0.10	0.00	-0.10	-0.10	1.00									
8	*Pers	0.00	0.00	0.00	0.00	0.00	0.00	-0.20	1.00								
9	Fert- p	-0.10	-0.10	-0.10	0.00	-0.10	-0.10	0.10	-0.20	1.00							
10	Fert-m	-0.20	-0.20	-0.20	0.00	-0.10	-0.10	0.10	-0.20	0.00	1.00						
11	*Ce-p	0.10	0.10	0.10	0.10	0.10	0.20	0.15	0.00	0.00	0.00	1.00					
12	*Ce-m	-0.10	-0.10	-0.10	-0.10	0.10	0.10	-0.15	0.00	0.00	0.00	0.00	1.00				
13	*Sb-p	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.80	0.00	1.00			
14	*Sb-m	0.00	0.00	0.00	-0.10	0.00	0.00	-0.15	0.00	0.00	0.00	0.00	0.80	0.00	1.00		
15	MR	-0.25	-0.25	-0.25	0.00	0.00	0.00	0.20	-0.10	0.10	0.10	0.00	0.00	0.00	0.00	1.00	
16	*SCS	0.25	0.25	0.25	0.00	0.00	0.00	-0.10	0.10	-0.10	-0.10	0.00	0.00	0.00	0.00	-0.70	1.00
	parameter																
	s_A	350	15	11	47	.25	1,14	180	1	5	5	1	1	1	1	1	1
	reliabilities																
	Cow	.45	.45	.45	.20	.20	.20	.20	.35	.25	.25	.25	.25	.25	.25	-	.35
	Sire A	.80	.80	.80	.70	.60	.70	.45	.70	.70	.50	.70	.60	.70	.60	-	.80
	Sire B	.99	.99	.99	.99	.95	.99	.80	.90	.85	.85	.85	.85	.85	.85	-	.95

Carrier = fat and protein milk yield, Fat = Fat yield, Protein = Protein yield, Dg = daily gain, EUROP= EUROP- grading score, Dp = dressing percentage, Pers = Persistency, Long. = Longevity, Fert- p = Fertility paternal, Fert-m = Fertility maternal, Ce-p = Calving ease paternal, Ce- m = Calving ease maternal, Sb-p = Stillbirth paternal, Sb-m = Stillbirth maternal, MR = Mastitis resistance, SCS = Somatic cell count

* For these traits higher values are undesirable.

3. Results

3.1. Economic weights

The considered quota did not have an influence on the economic weights for beef performance traits and functional traits. In Table 5 absolute economic weights for all the traits considered are given per genetic standard deviation. Additionally the relative economic weights in relation to the most important trait, protein yield, are given.

Better fertility (conception rate) resulted in a lower percentage of infertility culling. The economic effects of better fertility were mainly lower costs for inseminations, shorter calving intervals, less need of female calves for replacement and a higher length of productive life. As length of productive life was a separate trait in the TMI, the difference in profit due to improved herdlife after changing the conception rate was subtracted from the economic value of fertility to avoid double-counting (Dempfle, 1992). This has to be kept in mind when comparing the economic value for fertility with the results from other studies where such a correction was not performed. The economic value for conception rate depended on the level of fertility assumed for the population. Such a non-linearity of the economic value for fertility was also found by Boichard (1990), Dekkers (1993) and Böbner (1994). The absolute economic value of ATS 25.- per percentage point of conception rate was in the range of the results of Boichard (1990) and Dekkers (1993) but lower than the results of Böbner (1994).

Table 5: Economic weights under a quota on the sum of fat and protein yields

Trait	Economic weights in ATS absolute per s_A	relative to protein yield
Carrier	-10.-	-0.02
Fat yield	345.-	0.87
Protein yield	396.-	1.00
Daily gain	155.-	0.39
EUROP	58.-	0.15
Dressing-%	155.-	0.39
Longevity	306.-	0.77
Fertility	100.-	0.25
Stillbirth	55.-	0.14
Calving ease	24.-	0.06
Mastitis resistance	200.-	0.50
Persistency	40.-	0.10

The economic weights for the reproduction traits calving ease and stillbirth were lower than those for fertility or longevity. The standardised economic weight for calving ease represented just 6 % of the economic weight for protein yield. This result is similar to Dekkers (1994). The economic weight for stillbirth depended mainly on the value for the calf and was approximately twice as high as the economic weight for stillbirth. Mack (1996) and Weidele (1996) found also higher economic weights for stillbirth than for calving ease.

3.2. Index selection

The results given in this chapter are intended to provide some indication of the effects of selection according to the TMI presented in this paper. For the calculation of the index weights (b-values) in Table 6 which are standardised per genetic standard deviation a selection intensity of 1 was assumed. The economic weights were the same for all individuals (see Table 7).

When interpreting the expected selection responses in Table 7 one should be aware of the assumptions. The true selection responses depend on the breeding programme as a whole and cannot be calculated whith such simple examples.

Table 6: Standardised b-values depending on the assumed reliabilities

trait	b-values cow	Sire A	Sire B
Carrier	265	146	5
Fat	354	316	331
Protein	347	304	376
Dg	192	168	159
Europ	78	65	55
Dp	77	115	144
Long.	312	315	327
Pers	138	100	61
Fert- p	90	98	103
Fert-m	60	85	99
Ce-p	2	13	25
Ce-m	127	78	43
Sb-p	48	56	56
Sb-m	97	65	51
SCS	103	130	137

For an explanation of the abbreviations used and for reliabilities of estimated breeding values assumed for cow, Sire A and Sire B see Table 4.

Although the economic weight for some functional traits is very high, the expected selection response in these traits is much lower. The main reasons for the higher selection response in the milk production traits are: very high economic weights for fat and protein yield, high positive correlations between the milk production traits, unfavourable correaltions between the milk production traits and some functional traits, low genetic correlations between the functional traits and the lower reliabilities for the EBVs of the functional traits.

The positve effect of breeding according to a TMI on the expected selection response of the functional traits can be seen in Table 8. Table 8 includes standardised selection responses for the various traits depending on the traits included in the aggregate genotype. For MV only the milk production traits were included in the aggregate genotype and in the selection index. In case of the TMI all traits were included. For the calculations of the results in Table 8 the reliabilities for the EBVs were assumed as for sire A. In this case breeding according to a TMI resulted in a monetary selection response which was more than 10 % higher compared to breeding according to the ”Milk value”.

Table 7. Selection responses per generation by an assumed selection intensity of unity

			Cow			Sire A			Sire B		
trait	unit	w	SR(s_A)	SR(n)	SR(m)	SR(s_A)	SR(n)	SR(m)	SR(s_A)	SR(n)	SR(m)
Milk	kg	0.-	.69	242	0.-	.73	255	0.-	.70	244	0.-
Fat	kg	345.-	.69	10.4	239.-	.75	11.3	259.-	.76	11.4	261.-
Protein	kg	396.-	.71	7.8	282.-	.77	8.4	303.-	.77	8.5	304.-
Dg	g	155.-	.20	9.4	31.-	.31	14.8	49.-	.35	16.4	54.-
Europ	class	58.-	-.01	-.01	-1.-	.04	0.01	3.-	.07	.02	4.-
Dp	%	155.-	-.10	-.12	-16.-	-.04	-0.05	-6.-	.01	.01	1.-
Long.	day	306.-	.07	14	23.-	.17	31	53.-	.30	54	93.-
Pers	s_A	40.-	.13	.13	5.-	.20	.20	8.-	.21	.21	8.-
Fert- p	%	100.-	-.01	-.04	-1.-	.05	.25	5.-	.06	.32	6.-
Fert-m	%	100.-	-.10	-.51	-10.-	-.08	-.40	-8.-	-.04	-.17	-3.-
Ce-p	s_A	24.-	-.07	-.07	-2.-	-.06	-.06	-1.-	-.05	-.06	-1.-
Ce-m	s_A	24.-	.20	.20	5.-	.25	.26	6.-	.27	.27	6.-
Sb-p	s_A	55.-	.01	.01	1.-	.04	.04	2.-	.05	.05	3.-
Sp-m	s_A	55.-	.11	.11	6.-	.16	.16	9.-	.17	.17	9.-
MR	s_A	200.-	-.12	-.12	-23.-	-.05	-.05	-10.-	-.01	-.01	-3.-
$R^2(\hat{A}_T)$					.48			.75			.92

s_A = genetic standard deviation, w = economic weight per s_A, $R^2(\hat{A}_T)$ = Reliability of the estimated TMI
SR(m) = selection response in ATS, SR(s_A) = selection response in s_A, SR(n) = selection response in trait units

For an explanation of the abbreviations of trait names for reliabilities of estimated breeding values assumed for cow, Sire A and Sire B see Table 4.

Table 8. Standardised selection response per generation depending on the traits included in the aggregate genotype (MV = selection for milk production traits only, TMI = selection for the total merit index)

	Standardised selection response in s_A	
Trait	MV	TMI
Carrier	.88	.73
Fat	.90	.75
Protein	.92	.77
Dg	.15	.31
Europ	-.05	.04
Dp	-.15	-.04
Long.	-.10	.17
Pers	.00	.20
Fert- p	-.10	.05
Fert-m	-.20	-.08
Ce-p	-.10	-.06
Ce-m	.10	.26
Sb-p	.00	.04
Sb-m	.01	.16
MR	-.25	-.05

For an explanation of the abbreviations used see Table 4.

4. Conclusions

Functional traits should be included in the aggregate genotype according their economic weights. Selection for a TMI will result in higher economic efficiency. With exception of the traits fertility (maternal), calving ease (paternal) and mastitis resistance negative selection responses could be avoided in the functional traits. The results on the effect of the use of a TMI on selection response are preliminary as many parameters of a breeding programme (like different selection intensities in different selection pathways) were ignored in this study.

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