For Measuring the Impact of Change in Selection Indexes, Old Ways are Best

***E.P. Cunningham*[1] *and H. Täubert*[2]**
[1]*Department of Genetics, Trinity College Dublin, Ireland*
[2]*Institute of Animal Breeding and Genetics, University of Göttingen, Germany*

Abstract

Genetic selection indexes for dairy cattle, originally aimed at production traits only, have been expanded in stages over the past 30 years to include up to 12 traits covering production, functionality, health and fertility. Each addition to the selection goal involves the use of additional measured phenotypic variates. The net effect of these additions is usually described as causing change in the "Relative Emphasis" of different traits, though there are varying definitions of what this means.

We suggest that this term is inappropriate, and show that as usually used it overstates the net impact of the changes. We propose instead that two long established statistics be used. These are:

The Relative Value(RV) of each target trait, defined as the percent of total economic value of genetic gain in all traits attributable to gain in that particular trait.

The Relative Contribution(RC) of each measured variate, defined as the percent reduction in total economic value of overall genetic gain if that particular variate is omitted from the index.

The result of applying these measures is contrasted with the use of current methods using US Holstein data.

Introduction

The original formulation of selection index theory (Hazel, 1943) distinguished clearly between the Aggregate Genotype, composed of a (usually linear) combination of geno-typic values of the candidates for selection on the one hand, and the Selection Index, a linear combination of phenotypic variates measured on those candidates and/or their relatives. Over the years, statistical models representing phenotypic data, and methods of calculation, have become more sophisticated. Terminology has also changed. However, the essential distinction between the defined aggregate genotype (now called TEM, total economic merit, Shook, 2006) and the calculated Selection Index(SI) remains.

Changes can be made in the definition of TEM by adding or deleting traits, and by altering their pre-assigned economic values. Changes will also result from the addition or deletion of measured variates in the SI. The implementation of changes in either case will alter the amount of genetic gain resulting from selection, as well as its distribution over the target traits. However, there is an important distinction. Changes made in the TEM incur no direct costs. They may, however, have consequential costs (or gains) in terms of the amount and kind of genetic change achieved. Change in the measured variates used in the SI, on the other hand, has both direct and consequential cost implications. Additional expenditure is required, for example , to record somatic cell scores in daughter groups. Investment in a selection programme therefore requires careful calculation and balancing of the costs and consequences of changes to both the TEM and the SI.

As dairy cattle selection indexes have evolved over the last 30 years, it has generally been the case that the addition of new traits to the TEM has been accompanied by the recording of new variates in the SI. This has obscured the reality that traits which might or might not be included in the TEM will change as correlated responses even if corresponding variates have not been measured. Until recently these correlated (and generally negative) responses were not calculated. The total economic value of genetic gains achieved was therefore overestimated.

Apart from the calculation of overall economic gains from selection, there is considerable interest in the way in which changes in the TEM or the SI affect the distribution of total gains over the various target traits. The most frequently used term to describe this is the change in the "Relative Emphasis" this produces for the different traits. Relative Emphasis for a trait is defined(Van Raden, 2002) as " economic value times standard deviation divided by the sum of the absolute values of these products, then multiplied by 100". Miglior(2005) used a different definition, dividing instead of multiplying economic values by standard deviations. The essential feature of both of these definitions is the attempt to standardise across traits by multiplying(or dividing) each one by its genetic standard deviation and expressing the results as percent of the sum of these products. Shook (2006) compared indexes using the same statistic as VanRaden (2002), but using the term 'relative economic weights', while the trade journal *Holstein International*(2006*)* compared indexes across countries using a 'composition of the total indexes' measure which was not defined. Clearly these different approaches to the same question are likely to give different results. In addition, the general term 'Relative Emphasis', while intuitively appealing, is difficult to relate either to the expenditure devoted to selection on particular traits or the genetic and economic consequences of that selection.

We suggest that more appropriate measures (developed many years ago, Cunningham, 1972) give more meaningful results. To begin with it is necessary to distinguish again between *target traits* included in the TEM and *measured variates* included in the SI. We can calculate an appropriate measure of the value of each trait included in the TEM by calculating the percent reduction in the total economic value of genetic change in all traits if that particular trait is omitted. This calculation is independent of whether or not a corresponding phenotypic measure has been included in the index. We call this the Relative Value(RV) of each target trait.

A parallel statistic can be calculated to describe the Relative Contribution (RC) of each measured variate. This is defined as the percent reduction in total economic value of overall genetic gain if that particular variate is omitted from the index.

Materials and Methods

The use of these measures of Relative Value (RV) of target traits and Relative Contribution (RC) of measured variates is illustrated using the latest (June 2006) economic weights and genetic and phenotypic parameters for the US Holstein population (USDA, 2006). Table 1 lists the ten traits, the units in which they are measured, the value of each unit and the year in which this trait was added to the index. They are grouped into three groups: Production, Functionality, Health/Fertility. These data were used to construct selection indexes, assuming that all variates are measured on progeny groups of 75 daughters.

Table 1. Traits included in this study. Detailed definitions and derivation of economic values are from USDA, 2006. Year of addition to USDA index is from VanRaden *et al.* 2004.

TRAIT	UNITS	VALUE 2006 ($/PTA Unit)	YEAR ADDED	GROUP
Milk	Pounds	0	1971	
Fat	Pounds	2.70	1971	Production
Protein	Pounds	3.55	1976	
Size	Composite	-14	2000	
Udder	Composite	28	2000	Functionality
Feet/legs	Composite	13	2000	
Productive life (PL)	Months	29	1994	
Somatic Cell Score (SCS)	Log	-150	1994	
Daughter Pregnancy Rate (DPR)	Percent	21	2003	Health/Fertility
Calving Ability (CA)	Dollars	1	2003	

Results

The overall gain from selection on any index is proportional to the standard deviation of the index (σ_I). This in turn is a function of the traits included in the TEM, the economic weights assigned to them, the measured variates used in constructing the index, and the three matrices of genetic and phenotypic correlations linking all of these together. Table 2 shows the relative genetic gains from three indexes which correspond approximately to the sequential development of the USDA index. The first contains production traits only, the second production and functionality traits, and the third production, functionality and health/fertility traits. Two versions of each index are used (a) assuming only traits corresponding to measured variates are included in the TEM and (b) where all ten traits are included in the TEM, and account is taken of the economic consequences of correlated genetic responses in all traits.

Table 2. Relative genetic gain from selection on three selection indexes for (1) production only, (2) production + functionality, (3) production + functionality + health/fertility. Indexes are calculated (a) assuming only traits corresponding to measured variates are included in selection goal and (b) taking account of correlated responses in all traits.

	Index 1		Index 2		Index 3
	(a)	(b)	(a)	(b)	(a,b)
σ_I	71.76	68.61	70.12	71.70	74.6
Relative σ_I	100	95.6	98.2	99.91	103.4

It can be seen, with the parameters used, that the first, simple, production index overstated the economic gain from selection by 4.4%, because it did not take account of the negative genetic change in traits not measured. Index 2, in which measured variates include functionality as well as production, recovers most of this difference, while for index 3, where all ten traits have corresponding measured variates there was an improvement of 3.4% in economic value of total gain.

The remarkable thing about these results is how small the differences are. This suggests that, with the parameters and economic weights used, the net penalty for using the simplest, production only, indexes was small while the gain from adding seven additional measured varitets was also modest.

Table 3 shows the relative value (RV) of different target traits for the same three indexes, again (a)ignoring or (b)taking account of correlated responses in traits for which no corresponding variate was measured.

The results again contrast with those using the "Relative Emphasis" approach. Including fat is, in all cases more valuable in the TEM than protein. Under index 1 (selecting on production only) the correlated responses in the remaining seven traits have relatively modest value in the index. Under indexes 2 and 3, the relative value of these traits is generally enhanced, but not greatly. In all cases, the two production traits, fat and protein, are overwhelmingly the most important. Productive Life(PL) is the most important of the other seven traits.

Table 3. Relative value (RV) of different target traits in three selection indexes for (1) production only, (2) production + functionality, (3) production + functionality + health/fertility. Relative value of a trait is defined as percent of total genetic gain from selection on the index attributable to genetic change in that trait. RVs are calculated (a) assuming only traits corresponding to measured variates are included in selection goal and (b) taking account of correlated responses in all traits.

	Index 1		Index 2		Index 3
	(a)	(b)	(a)	(b)	(a,b)
Milk	0	0	0	0	0
Fat	51,2	53.5	51.0	48.6	44.9
Protein	48.8	51.1	48.7	46.4	42.8
Size		1.2	2.1	2.6	2.4
Udder		-3.3	-1.8	-0.07	-0.03
Legs + Feet		-0.1	0.07	0.26	0.2
PL		2.3		5.1	8.6
SCS		-2.7		-1.7	0.12
DPR		-3.0		-2.6	-1.3
Calving ability		1.1		1.4	2.2

Table 4. Relative contribution (RC) of different measured variates in three selection indexes for (1) production only, (2) production + functionality, (3) production + functionality + health/fertility. Relative contribution of a variate is defined as percentage reduction in total genetic gain if that variate is omitted from the index. RCs are calculated (a) assuming only traits corresponding to measured variates are included in selection goal and (b) taking account of correlated responses in all traits.

	Index 1		Index 2		Index 3
	(a)	(b)	(a)	(b)	(a,b)
Milk	0.05	0.08	0.06	0.07	0.07
Fat	10.19	10.10	10.16	9.92	8.70
Protein	4.60	5.12	4.67	4.66	4.09
Size			0.79	2.18	0.96
Udder			0.77	3.15	1.02
Legs + Feet			0.14	0.44	0.16
PL					0.91
SCS					0.30
DPR					0.11
Calving ability					0.43

The relative contributions (RC) of different measured variates for the same three selection indexes are shown in Table 4. The figures here are generally very small. The greatest loss would be if fat is dropped from the list of measured variates. This is largely because it has a higher standard deviation than protein. Because all traits, particularly the main production traits, are linked by strong genetic and phenotypic correlations, if any one is dropped from the list of measured variates, the reduction in total selection gain is relatively small.

In general, these results suggest that we may have been overestimating the net economic consequences of the changes that have been made in dairy selection indexes over the last thirty years. The two production traits protein and fat still dominate the contribution of target traits included in TEM and the value of measured variates used in the index.

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