Females in MACE: Resolving double counting using the reverse reliability approximation.

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Abstract

Including females' estimated breeding values (EBVs) in Multiple Across-Country Evaluation (MACE) requires a way to prevent information shared through relatives from being counted more than once. This paper evaluates a reverse reliability approximation that converts submitted reliability into an adjusted effective daughter contribution (EDC) after accounting for pedigree information. The results focus on five Ayrshire populations contributing with female data: Australia, Canada, Great Britain, the United States, and South Africa. For cows, mean adjusted EDCs and reliabilities were compared with submitted national values for milk, fat, and protein. Adjusted mean EDCs were equal to or lower than national means in almost all population and trait combinations, with the largest reductions observed for Great Britain. Mean female MACE (FMACE) reliabilities were generally close to, but often lower than, national reliabilities; South Africa was the exception, with higher FMACE mean reliability for all three traits. Bull comparisons between conventional MACE and FMACE showed that adding female information increased international reliability across the participating populations. These results support the use of the reverse reliability approach as a practical mechanism for controlling double-counting when female information is incorporated into MACE. The results also show why EDC is central to the procedure: it represents the amount of information retained for an animal after reliability attributable through relatives has been accounted for.

Key words: International evaluations, MACE, small populations, females in MACE

Introduction

Multiple Across-Country Evaluation (MACE) combines national genetic evaluations across countries and provides international breeding values expressed on each participating country's scale (Schaeffer, 1994). The females in MACE work extend this framework by allowing cow EBVs to contribute to the international evaluation (Mugambe et al., 2025). The principal technical concern is double-counting: A cow EBV contains information from the cow itself and from relatives; some of those relatives may be A.I. bulls included in the MACE evaluation. If the full reliability of every submitted proof is treated as independent information, shared information can receive more weight than intended.

The approach examined here addresses this overlap through a reverse reliability approximation. Instead of using submitted effective daughter contributions (EDC) directly, reliability is reversed to estimate the contribution needed after information attributable to relatives has been considered. The adjusted EDC is therefore intended to represent the information that remains available to weigh an animal in female MACE (FMACE)

after any possible overlapping through pedigree has been accounted for. The objective of this paper is to present the results for cows and bulls and to assess whether the resulting pattern is consistent with a useful correction for double-counting.

Materials and Methods

Production trait data for milk, fat, and protein were evaluated for five Ayrshire populations contributing with female proofs from Australia (AUS), Canada (CAN), Great Britain (GBR), the United States (USA), and South Africa (ZAF). The analysis used the existing MACE framework with female records added to create the FMACE evaluation.

Sources of double-counting

The inclusion of female EBVs in MACE poses a risk of double-counting. In conventional MACE, a bull's EDC already represents information contributing to his national evaluation, including information from his daughters. The same problem occurs among females because a cow's EDC can contain information from her own records, progeny and further descendants, while those related animals may also enter the evaluation with their own EDCs. For example, information from a bull may contribute to the EDC of his dam while the bull simultaneously contributes his own EDC to MACE. Consequently, simply combining the EDCs supplied for bulls and cows would treat overlapping information as if it were independent, potentially inflating the amount of information entering the evaluation and affecting the resulting reliabilities. The purpose of deriving adjusted EDCs (EDCadj) is therefore to partition the available information among related animals so that information already represented through relatives is not counted again when both bulls and cows are included in MACE.

The reverse reliability procedure

The reverse reliability procedure uses reliability, pedigree, and trait heritability to approximate an animal's effective contribution after accounting for reliability attributable to relatives. This follows the logic of the Harris and Johnson (1998) approximate animal model reliability calculation, applied in reverse. Reliability from two information sources, x and y, is combined as shown below.

$$R(x+y) = \frac{[R(x) + R(y) - 2R(x)R(y)]}{[1 - R(x)R(y)]}$$

And this can be reversed to recover the reliability attributable to one source:

$$R(x) = \frac{[R(x+y) - R(y)]}{[R(x+y)R(y) + 1 - 2R(y)]}$$

This algorithm was implemented iteratively, looping through countries in the MACE pipeline one at a time, using APAX99 to obtain adjusted EDCs free of double counting. The resulting adjusted EDC is then used as the information weight in FMACE. Cow results were summarized as population means for national EDC, adjusted FMACE EDC, national reliability, and FMACE reliability. Bull results were summarized by comparing the mean reliability of conventional MACE with the corresponding FMACE reliability after including female information.

Results & Discussion

The cow results (Table 1) show directly how the reverse reliability adjustment changes the amount of information assigned to female proofs. Across the five populations, adjusted mean EDCs were never higher than national mean EDCs except for South African milk, where both means were 9. The size of the adjustment differed considerably among populations, indicating that the amount of reliability attributable through relatives is population-specific rather than a fixed proportion of the submitted proof.

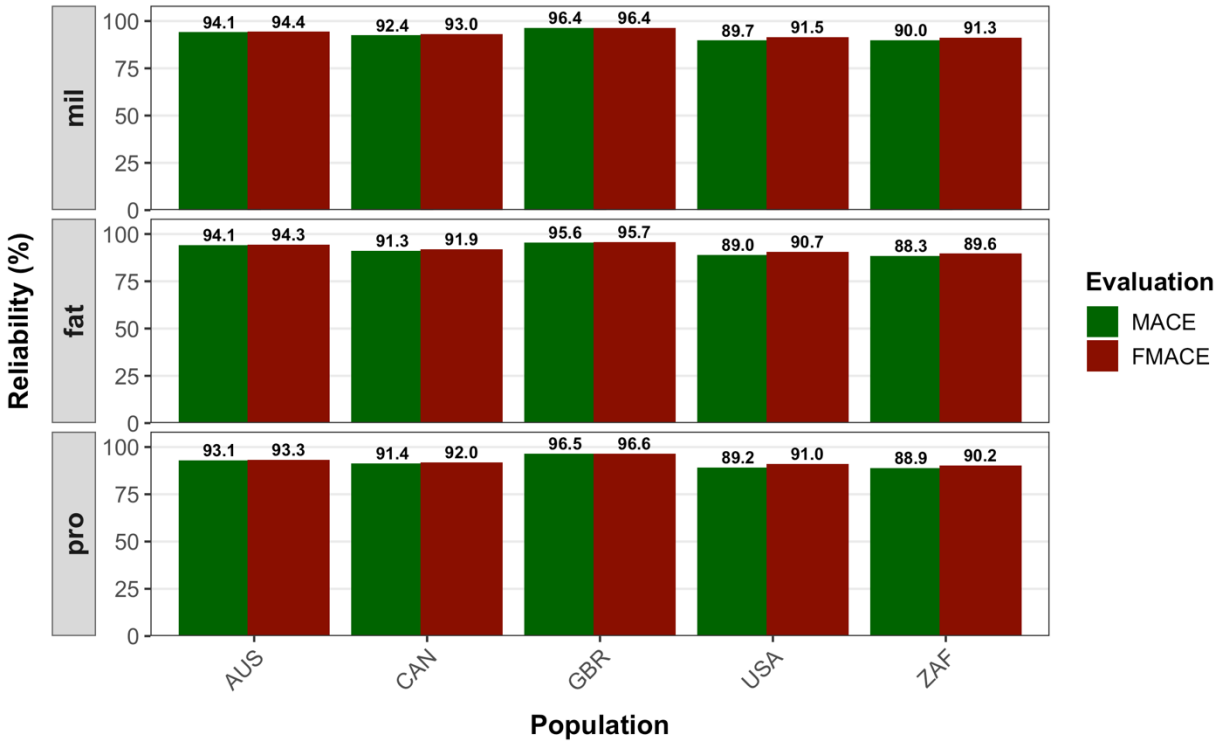


Figure 1. Comparison of bull reliability in conventional MACE and FMACE

Table 1: Mean EDC and reliability of cows before and after the reverse reliability adjustment for milk, fat and protein.

Trait	Pop	N	EDC_{nat}	EDC_{adj}	rel_{nat}	$Frel_{int}$
Milk	AUS	25,990	10	10	63.39	63.31
	CAN	10,817	16	12	63.94	63.48
	GBR	84,731	11	6	59.96	57.77
	USA	108,496	8	8	48.22	46.61
	ZAF	38,495	9	9	51.18	52.10
Fat	AUS	25,973	10	10	64.45	64.32
	CAN	10,821	16	15	63.93	63.47
	GBR	84,767	14	7	59.95	57.77
	USA	107,991	7	7	46.20	44.39
	ZAF	38,564	13	12	47.14	48.35
Protein	AUS	25,709	7	7	55.13	54.62
	CAN	10,814	14	14	63.93	63.46
	GBR	84,750	15	6	59.95	57.79
	USA	108,613	9	9	49.46	47.99
	ZAF	38,708	10	10	49.69	50.77

Pop; Population, **EDC_{nat};** National EDC, **EDC_{adj}**;Adjusted EDC, **rel_{nat};** National reliabilities, **$Frel_{int}$;**FMACE reliability

The largest EDC reductions were observed for GBR. For milk, mean EDC declined from 11 to 6; for fat, from 14 to 7; and for protein, from 15 to 6. CAN declined from 16 to 12 for milk and from 16 to 15 for fat, while protein remained at 14. AUS changed little, with equal, rounded mean EDCs for milk and fat and no change for protein. The USA also showed no change in the rounded mean EDCs for the three traits. These results illustrate the purpose of the correction: adjusted EDC is not intended to reproduce the submitted EDC, but to represent the information remaining after overlap through relatives is accounted for.

Mean cow reliabilities (Figure 1) were close between the submitted national values and FMACE, but the direction and magnitude differed across populations.

The reliability results reinforced the importance of interpreting FMACE using the information weights derived from the reverse procedure. Lower mean FMACE reliability does not by itself demonstrate a poorer evaluation because the procedure deliberately removes information represented through relatives from the independent contribution assigned to a cow. Possible causes of these discrepancies may include variations in data quality across countries, such as incomplete pedigrees, and inconsistencies in reliability estimation methods.

The bull results provided the complementary test of whether female information contributes to the international evaluation after the double-counting correction. In Figure 1, FMACE reliability is higher than conventional MACE reliability for the displayed participating populations across milk, fat, and protein. The increases are generally modest. This is consistent with the objective of the reverse reliability approach: only information that remains after accounting for overlap should receive additional weight. The value of the result is therefore not the size of the increase alone, but that female information can add reliability to bulls after the information weights have been adjusted to control double-counting.

Together, the cow table and bull figure place EDC at the centre of the results. The cow table shows how much the information weight can change after reversal, while the bull figure shows the consequence of allowing the resulting female information into MACE. The combination supports an interpretation in which reverse reliability is used first to separate overlapping information and adjusted EDCs, and then determine how much information each proof contributes to FMACE.

Conclusions

These results show that the reverse reliability approximation provides a practical way to control double-counting when female EBVs are introduced into MACE. Its most important output is the adjusted EDC, which represents the information retained for an animal after reliability attributable through relatives has been considered. The cow results demonstrate that this adjustment can be substantial in some populations and small in others.

Across milk, fat, and protein, FMACE cow reliabilities remained close to submitted national reliabilities, although most population and trait means were slightly lower after the correction, and ZAF was consistently higher. The bull comparison showed higher FMACE reliability than conventional MACE in the displayed participating populations. Together, these results indicate that female information can contribute to MACE if all information contained in a cow proof is treated as independent. The key to the approach is therefore not simply the inclusion of more cows, but the use of adjusted EDCs to determine how much non-overlapping information each proof contributes.

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