Impact of Heterogeneity of Variance over Time on International Comparisons Using a Simulation Approach

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Introduction

The MACE program is the most accurate method currently available for carrying out international comparisons. The multiple-country model allows each country to have different genetic parameters, different units of measurement and genetic correlations among countries that might be less than one. Through the implementation and evaluation of this program, practical limits have however been identified, namely sensitivity to national genetic evaluations and sensitivity to variance components (Schaeffer, 1994). Different trends of sire standard deviations over time have been shown (Cassandro et al., 1996), that is, some countries have an irregular trend over time. These different trends may be due to differences in selection schemes: number of daughters per bull, number of bulls sampled per year and start year of a national progeny testing scheme. Other explanations might include the intensive use of few sires as bull sires, or the inclusion of a mix of different populations in the same evaluation.

A simulation study by Weigel et al. (1996) showed that the use of EBV only from bulls born after 1990 gave more correct proportion of elite bulls from each population and led to conversion equations which were nearly reciprocal. In order to provide the fairest comparison of elite bulls, INTERBULL decided then to adjust differences in time period spanned by individual country=s selection schemes, by editing the incoming data, using estimated breeding values from bulls born after 1980, only. Unfortunately, the problem still exists: trends of variance continue to be different across countries. Cassandro et al. (1997) suggested to apply a standardisation to de-regressed proofs to account for heterogeneity of variance of EBV within country over time on MACE evaluations. After standardisation by year of birth, re-ranking was evident together with changes of conversion factors and differences of average EBV. The authors suggested in their conclusions to carry out a simulation study to validate these results.

The objective of this study is to examine, through a simulation analysis, if heterogeneity of variance was a cause of bias for international comparisons using the MACE procedure.

Materials and Methods

Data were simulated for six generations for three populations with two different approaches, each one consisting of ten replicas. In the first simulation approach, the populations had three means and three different selection schemes resulting in different variance structures among three populations. Population 2 (POP2) had constant parameters of selection scheme across generations, while population 1 (POP1) and population 3 (POP3) had parameters of their selection scheme changing over time (Table 1). Population genetic means were set to 0, 10 and B10 units for POP1, POP2 and POP3, respectively.

In the second simulation approach, the three populations had the same mean (equal to zero) at generation zero and three different selection schemes resulting in much smaller different variance structures among population than simulation 1. Again, POP2 had constant parameters of selection scheme across generations, while POP1 and POP3 had parameters of their selection scheme changing over time (Table 2).

The three populations had equal heritability (.30), base phenotypic variance (100), and genetic correlation among them (.95) in both simulations.

In summary, simulations were characterised by:

! A population (POP1) with a relatively young selection scheme, doubling in the last 3 generations the number of bulls tested per generation, but with a decreasing progeny group size at the first evaluation. Moreover, the importation rate from the other populations decreases overtime, as well as the number of sires of bulls.

! A population (POP2) with a constant efficient selection scheme over time.

! A population (POP3) with an established selection scheme, increasing the number of bulls (simulation 1) and the progeny group size per generation, as well as the level of importation and number of sires of bulls (simulation 1).

Estimated breeding values were used to run the current procedure of MACE of INTERBULL. Bias was computed within population as MACE estimated breeding values minus true breeding values. Being the average genetic SD between 5 and 6 units, a bias of 1 unit is between 17 to 20% of the genetic SD. A second run of MACE on deregressed proofs, standardised per generation (Cassandro et al., 1997), was computed to investigate if standardisation might have been a possible preadjustment to account for heterogeneity of variance. The base variance used to standardise deregressed proofs within country was the variance of each country at generation four.

Results and Discussion

Trend of bull standard deviations

Differences in size and strategies of selection programmes caused heterogeneity of variance of bulls over time. Heterogeneity of variance was much higher for simulation 1 than simulation 2 (Figures 1 and 2). POP2 had a constant variance over time, while POP1 and POP3 had a decreasing variance at different rates. Differences in variances among populations were very small in simulation 2.

It should be noted that the level of heterogeneity of variance in the first simulation was a better prediction of the current field situation than the level in the second simulation: in the period 1981-90, sire SD increased by 26% for Germany and decreased by 44, 26, 21, 4 and 2% for Italy, Canada, The Netherlands, United States and France, respectively (Cassandro et al., 1996). In simulation 1, sire SD decreased by 42, 41 and 4% for POP1, POP3 and POP2, respectively; while, in simulation 2, sire SD decreased by 15, 6 and 4% for POP1, POP2 and POP3, respectively.

Bias in simulation 1

In Figures 3, 4 and 5 below, biases by generation in simulation 1 are plotted for POP1, POP2 and POP3 scales, respectively. Overall, biases were larger in generation one and two, and tended to decrease in the last three generations. The pattern of bias was quite different when the three population scales were compared. On POP1 scale, POP3 was the population with the lowest bias, very close to zero, while POP1 was underestimated by 1 unit, and POP2 had the highest bias, underestimated by 1.5 units. On the scale of POP2, POP1 had a very small bias close to zero, POP2 was underestimated by .8-1 unit, while POP3 was overestimated by 1-2 units. On POP3 scale, POP3 was underestimated by .8 unit, POP1 by 1-1.5 units, and POP2 had a larger bias of 2 units. Generally, when standardisation was applied to the deregressed proofs in simulation 1, bias was larger in generation 1 and 2, but closer to the bias of the normal run in subsequent generations.

Average effects on elite bulls are shown in Table 3, in which differences between the top 100 bulls according to MACE breeding values and the top 100 bulls according to their true breeding values are reported for the normal and standardised run in simulation 1. POP1 was underestimated in all populations, with 2 to 4 less bulls in the top 100. Underestimation was lower or equal to zero when standardisation was applied. POP2 was slightly overestimated on its own scale, while there was no bias in the other country rankings. However, there was a high underestimation for POP2 for the standardised run. POP3 had an opposite pattern to POP1 with an overestimation for all rankings in the normal run. The overestimation was even higher when the standardisation was applied. Overall, the effect of standardisation was not consistent for all populations, being less biased for POP1 than the normal run, and more biased for POP2 and POP3 than the normal run.

Bias in simulation 2

In Figures 6, 7 and 8, biases by generation in simulation 2 are plotted for POP1, POP2 and POP3 scales, respectively. Overall, biases were quite constant from generation 1 to 4, with a noticeable increase in the last generation. Differences across years within each population and scale were smaller than simulation 1. On the scale of POP1, there was a common bias of 1 unit for all populations. On the scale of POP2, POP1 and POP3 had a small bias, close to zero, while POP2 was overestimated by .8-1 unit. On the scale of POP3, there was a slight increasing bias overtime for POP1 and POP2, while POP3 was underestimated by .8 unit. When standardisation was applied to the deregressed proofs in simulation 2, the degree of bias was very close to the bias of the normal run.

Average effects on elite bulls are shown in Table 3, in which differences between the top 100 bulls according to MACE breeding values and the top 100 bulls according to their true breeding values are reported for the normal and standardised run for simulation 2. Ranking of the normal run was very similar to the ranking of the standardised run. Ranking of POP1 was correct on its own scale, while it was underestimated on the other population scales. POP2 was slightly overestimated on its own scale, while it was overestimated on the other country rankings. POP3 was overestimated in all populations, with the highest value on its own scale.

Conclusions

Trends of heterogeneity of variance within population over time were different in the two simulation approaches. The level of heterogeneity of variance of the current field situation was better predicted by simulation 1 than simulation 2. When heterogeneity of variance was present within country over time (simulation 1), there was a significant bias on MACE results. Bias was not constant over time and it changed direction (underestimation or overestimation) when different population scales were considered. In simulation 1, the effect of standardisation was not consistent for all populations, decreasing the bias for POP1 and increasing the bias for POP2 and POP3.

When there was small heterogeneity of variance (simulation 2), bias was smaller. Bias was more constant overtime, but it still differed when different population scales were considered. When standardisation was applied in simulation 2, the degree of bias was very close to the bias of the normal run.

Differences in number of bulls from each population between the MACE top 100 and the true BV top 100 indicate that there is a clear advantage for the population with an increasing progeny group size per generation together with a disadvantage for the population with a decreasing progeny group size per generation. This bias is present in both simulations and suggests that the de-regression of the proofs does not completely adjust for differences in number of daughters.

Results from this investigation suggest that MACE should account for the heterogeneity of variance in order to provide unbiased estimation of bull EBV. Further investigation is needed to identify the best practice to account for the effect of heterogeneity of variance on MACE results.

References

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Table 1. Summary of variables for simulation one.

		Generation					
Variable	Population	0	1	2	3	4	5
No. bulls tested	1	80	80	80	120	160	200
	2	320	320	320	320	320	320
	3	160	160	160	180	200	220
No. progeny per bull	1	80	80	80	70	60	50
	2	80	80	80	80	80	80
	3	80	80	80	90	100	110
No. cows (progeny test)	1	6400	6400	6400	8400	9600	10000
	2	25600	25600	25600	25600	25600	25600
	3	12800	12800	12800	16200	20000	24200
No. cows (2^{nd} crop)	1	3200	3200	3200	3200	4200	4800
	2	12800	12800	12800	12800	12800	12800
	3	6400	6400	6400	6400	8000	10000
No. 2^{nd} crop progeny/bull	1	200	200	200	200	200	200
	2	200	200	200	200	200	200
	3	200	200	200	200	200	200
No. sires of sons	1	16	16	16	12	10	8
	2	16	16	16	16	16	16
	3	16	16	16	18	20	22
No. sires of cows	1	16	16	16	16	21	24
	2	64	64	64	64	64	64
	3	32	32	32	32	40	50
Max imported sires of sons	1	8	8	8	6	6	6
	2	4	4	4	6	6	6
	3	4	4	4	6	8	10

Table 2. Summary of variables for simulation two.

		Generation					
Variable	Population	0	1	2	3	4	5
No. bulls tested	1	120	120	120	160	200	240
	2	240	240	240	240	240	240
	3	180	180	180	180	180	180
No. progeny per bull	1	75	75	75	65	55	45
	2	75	75	75	75	75	75
	3	75	75	75	90	105	120
No. cows (progeny test)	1	9000	9000	9000	10400	11000	10800
	2	18000	18000	18000	18000	18000	18000
	3	13500	13500	13500	16200	18900	21600
No. cows (2nd crop)	1	9000	9000	9000	9000	9000	9000
	2	9000	9000	9000	9000	9000	9000
	3	9000	9000	9000	9000	9000	9000
No. 2nd crop progeny/bull	1	300	300	300	300	300	300
	2	300	300	300	300	300	300
	3	300	300	300	300	300	300
No. sires of sons	1	10	10	10	10	10	10
	2	10	10	10	10	10	10
	3	10	10	10	10	10	10
No. sires of cows	1	30	30	30	30	30	30
	2	30	30	30	30	30	30
	3	30	30	30	30	30	30
Max imported sires of sons	1	8	8	8	6	4	2
	2	3	3	3	3	3	3
	3	0	0	0	2	5	8

Table 3. Differences between the top 100 bulls according to MACE breeding value and the top 100 bulls according to their true breeding value (simulation 1).

		Ranking		
		POP1	POP2	POP3
Normal run	POP1	-2	-4	-3
	POP2	0	2	0
	POP3	3	3	4
Standardised run	POP1	0	-2	-1
	POP2	-9	-6	-9
	POP3	10	9	11

Table 4. Differences between the top 100 bulls according to MACE breeding value and the top 100 bulls according to their true breeding value (simulation 2).

		Ranking		
		POP1	POP2	POP3
Normal run	POP1	0	-4	-4
	POP2	-2	1	-3
	POP3	2	3	7
Standardised run	POP1	0	-4	-4
	POP2	-2	1	-4
	POP3	3	4	9

Figure 1

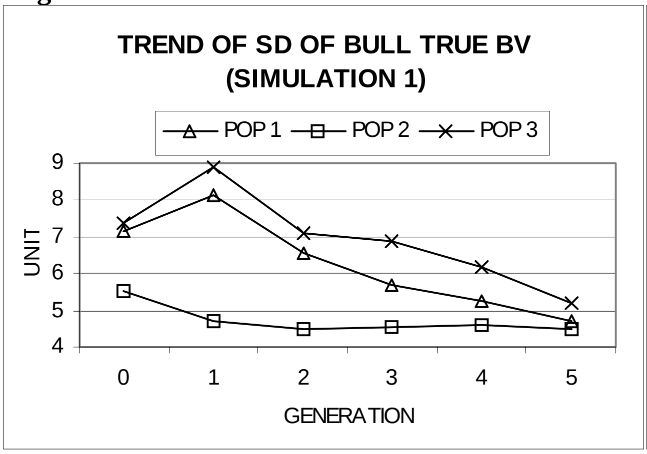
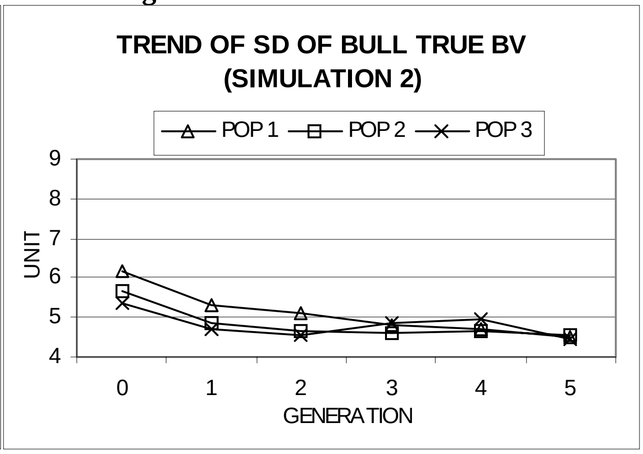
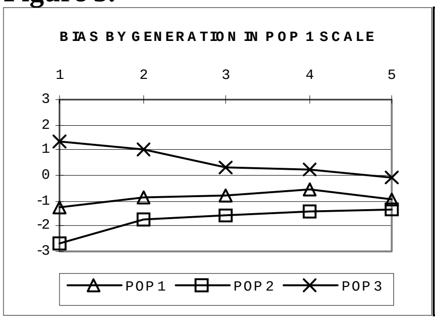


Figure 2



Simulation 1

Figure 3.



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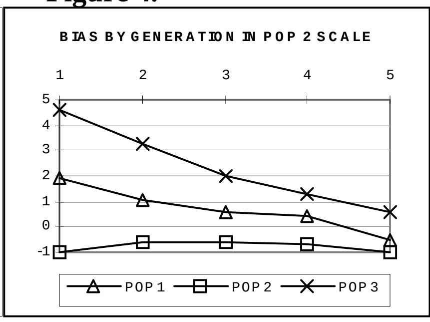

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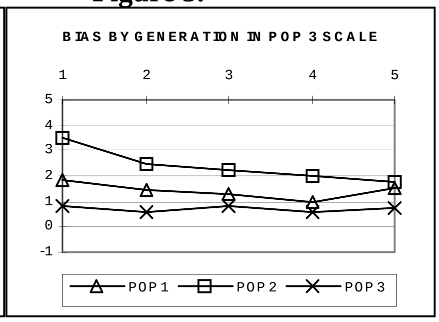

Simulation 2

Figure 6.

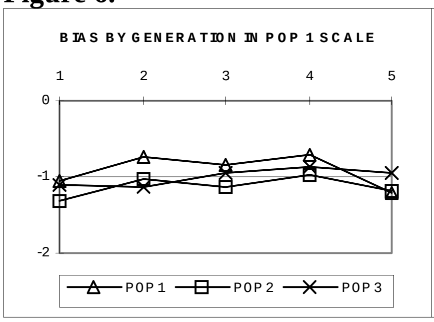

Figure 7.

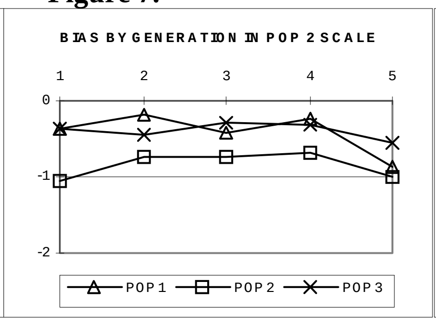

Figure 8.