Retrospective Analysis of the Accuracy of Conversion Equations and Multiple-Trait, Across-Country Evaluations of Holstein Bulls used Internationally

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ABSTRACT

In 1995, the multiple-trait across country genetic evaluation procedure replaced regression-based conversion equations as the preferred method for international genetic comparisons of dairy bulls. In the present study, February 1999 estimated breeding values of 632 foreign Holstein bulls that were used in Canada, Germany, Italy, The Netherlands, Sweden, and the US were compared with January 1995 predictions from home country data only. January 1995 predicted breeding values for each importing country were calculated using three methods: the multiple-trait, across-country evaluation procedure; conversion equations based on the multiple-trait, across-country evaluations; and conversion equations based on the Wilmink method. Mean correlations between 1999 estimated breeding values in the importing countries and 1995 predictions from international data were from 0.76 to 0.81 for all methods. The multiple-trait, across-country evaluation procedure is expected to lead to selection of different bulls, because bulls were allowed to be ranked differently in each country, but no significant increase in accuracy of selection was observed. The lack of improvement in accuracy of prediction was most likely due to limitations in data structure. International genetic comparisons are largely driven by data from a relatively small number of evaluated bulls with exported semen. Data from siblings and more distant relatives provide only weak, indirect genetic links between countries, and inclusion of such data seems to provide a minimal improvement in accuracy. Limitations in data structure might be alleviated by methods that define environments by climate or management factors rather than country borders.
(**Key words:** international conversion; multiple-trait, across-country evaluation)

Abbreviation key: MACE = multiple-trait, across-country evaluation; **REL** = reliability; **SD** = standard deviation.

INTRODUCTION

International selection of dairy sires can improve farm profitability through increased selection intensity and greater availability of elite genetics. However, many elite bulls have progeny in their home country only. Therefore, international genetic evaluations or conversion equations are needed to transform dairy sire EBV from an exporting country to the genetic base, scale, and units of measurement of an importing country. Prior to 1995, EBV in importing countries were typically predicted using conversion equations developed from linear regression analyses. Available procedures included the methods of Wilmink et al. (12) and Goddard (2), which were based on EBV and daughter yield deviations (9), respectively, of bulls with progeny in the importing and exporting countries. These methods share three limitations. First, relatively few bulls have progeny in both the importing and exporting countries. Second, progeny of expensive international bulls sometimes receive preferential treatment in the importing country, which can cause bias in a regression analysis. Third, accuracy of converted EBV of elite bulls can be lower than that of average bulls, because the EBV from the exporting country of elite bulls may exceed the range of data that were used to develop the conversion equations (10). The full-sib method (4), which uses daughter yield deviations of pairs of full-sibs with progeny in the importing and exporting countries, may be less susceptible to preferential treatment and can be calculated by using data of more recent bulls, but the number of full-sib pairs may be few. Conversion equations were typically applied by national genetic evaluation centers in each importing country, and, despite the limitations, these equations provided a reasonably effective way to compare the genetic merit of local and foreign bulls from 1985 to 1995 (5).

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In 1995, the Interbull Centre began calculating international dairy sire evaluations with data from North America and Europe. The multiple-trait across, country-evaluation (**MACE**) procedure (1, 8), an extension of multiple-trait BLUP in a sire-maternal grandsire model, was used. The MACE procedure is theoretically preferable to conversion equations, because all sires with progeny in each participating country can be evaluated simultaneously. In this manner, additional data from siblings, cousins, and other relatives can contribute to the accuracy of international sire evaluations. In addition, international comparisons are possible for pairs of countries that share few or no common sires. Furthermore, the MACE procedure allows sires to rerank across countries if genotype by environment interaction exists. However, the MACE procedure is still susceptible to the effects of preferential treatment of daughters of expensive international bulls, and a lack of genetic ties between countries can hinder estimation of the genetic correlation parameters needed to compute MACE EBV. The Interbull Centre routinely provides MACE EBV for all bulls that have been progeny tested in one or more member countries, in addition to conversion equations derived by simple linear regression of MACE EBV. These conversion equations can be used for cows, embryos, and breeder-evaluated bulls that do not receive a MACE EBV.

Although MACE is theoretically superior to regression-based conversion equations, its realized superiority, in practice, has not been evaluated. Because the Interbull Centre has provided MACE EBV for more than 4 yr, and because national EBV of numerous bulls with imported semen have become available during this time period, it is now possible to measure the accuracy of MACE relative to conversion equations. Therefore, the objective of this study was to assess the relative accuracy of MACE and conversion equations by comparing current EBV of Holstein bulls in six importing countries with historical predictions of their performance based on home country data only.

MATERIALS AND METHODS

Data

Data for the present study were from Holstein sires and consisted of January 1995 and February 1999 milk, fat, and protein EBV from Canada, Germany, Italy, The Netherlands, Sweden, and the US. The predictive ability of converted and MACE EBV was measured in a reference group of bulls that received national genetic evaluations based on imported semen in each of the six countries between January 1995 and February 1999. For each importing country, selected international bulls had no national genetic evaluation in January 1995 but had a national genetic evaluation with ≥80% reliability (**REL**) in February 1999. Two additional subsets of bulls were considered. First, international bulls were identified whose sires had a national genetic evaluation in the importing country in January 1995. Because the MACE procedure allows reranking of bulls between countries based on in-country performance of their relatives, one might hypothesize that MACE would perform better for international bulls whose sires already had milking daughters in the importing country. Second, international bulls whose January 1995 MACE EBV differed from the conversion line by ≥0.25 genetic standard deviations (**SD**) were identified. For these bulls, genotype by environment interaction was predicted by MACE, so it may be of interest to evaluate whether or not this prediction was justified.

Predicted Performance in the Importing Country

Three methods were used to predict progeny performance in the importing country from January 1995 home country data: conversion equations of Wilmink et al. (12), MACE conversion equations (1), and MACE EBV (1, 8).

The conversion equations of Wilmink et al. were calculated for each pair of countries by using bulls born from 1979 to 1988 (the most recent 10-yr period with complete data) that had ≥75% REL in both the importing and exporting countries. Performance in the importing country was predicted as

$$EBV_{IMP} = a + b\ EBV_{EXP}$$

where EBV_{IMP} and EBV_{EXP} are EBV in the importing and exporting countries, respectively, a is an estimate of the genetic base difference between the two countries, and b is a scaling factor that accounts for the ratio of genetic SD between the two countries. Coefficients of the conversion equation, a and b, were calculated in the following manner. Let

$$EBV^{*}_{EXP} = (EBV_{EXP} - \text{mean}\ (EBV_{EXP}))\ REL_{IMP}$$

where REL_{IMP} = REL in the importing country. A linear regression model was applied in which EBV_{IMP} was the dependent variable and EBV^{*}_{EXP} was the independent variable. The b coefficient of the conversion equation of Wilmink et al. was the estimated slope coefficient from this regression equation. The a coefficient of the Wilmink conversion equation was calculated as

$$a = \text{mean}\ (EBV_{IMP}) - b\ (\text{mean}\ (EBV_{EXP})).$$

The Wilmink conversion equations were applied to 1995 national EBV from the exporting country (i.e., country of original progeny test). For bulls that were simultaneously progeny tested in multiple countries, data from the country with the most progeny were used.

The MACE conversions were calculated for each pair of countries by using all bulls born in 1985 or later that were originally progeny tested in the exporting country. Local performance of international bulls was again predicted using a linear regression equation of the following form:

$$EBV_{IMP} = a + b\ EBV_{EXP}$$

where EBV_{IMP} and EBV_{EXP} are EBV in the importing and exporting countries, respectively, and a and b are intercept and slope coefficients as described earlier. In this case, coefficients of the conversion equation, a and b, were calculated using simple linear regression with MACE EBV_{IMP} as the dependent variable and MACE EBV_{EXP} as the independent variable.

The MACE EBV used in the present study (including development of the MACE conversions) were calculated by the Interbull Centre using January 1995 data from nine countries: Canada, Denmark, Germany, Finland, France, Italy, The Netherlands, Sweden, and the US. Several changes have occurred in the MACE procedure, as applied by the Interbull Centre, since 1995. These changes have included: acceptance of second-country data of bulls progeny tested in another country, exclusion of (Holstein) bulls more than 17 yr old at the time of evaluation, and adoption of a REML-type algorithm for estimation of genetic correlations between countries. Therefore, current (February 1999) MACE methodology was applied to January 1995 data of the nine aforementioned countries. Although data from nine countries were included in the MACE analysis, only six countries provided data that could be used to compare the accuracy of converted and MACE EBV. French data were not usable, because data of international, evaluated bulls with second-crop daughters in France were not included in the MACE analysis. Finnish data were also excluded, because data for one trait (fat yield) were missing. Finally, Danish data could not be used, because data submitted for the MACE analysis were on a different scale from official January 1995 national genetic evaluations (that were used to develop Wilmink conversion equations).

Evaluation of the Accuracy of Each Method

Accuracy of January 1995 predicted EBV using MACE, MACE conversions, or Wilmink conversions was measured as the correlation between these predictions and the actual February 1999 national EBV in the importing country. Bulls that received their first genetic evaluation (≥80% REL) based on imported semen between January 1995 and February 1999 were included in the correlation analysis. Changes may have occurred in some national evaluation systems between 1995 and 1999, but relative correlations should be unaffected. Correlations were also calculated for the two aforementioned subsets of international bulls: 1) bulls whose sires had a national genetic evaluation in the importing country in January 1995, and 2) bulls whose MACE EBV differed from the conversion line by ≥0.25 genetic SD. Product-moment correlations between 1995 predicted EBV and 1999 actual EBV were calculated by trait and importing country. In addition, we calculated the proportion of selected bulls that were in common when selection was based on actual 1999 EBV and each of the 1995 predictions. Finally, to determine whether each of the 1995 prediction methods led to selection of the same bulls, we calculated the proportion of selected bulls that were in common when selection was based on each possible pair of 1995 prediction methods.

Table 1. Number of international bulls that received their first genetic evaluation based on imported semen between January 1995 and February 1999, by country of importation.[1]

Country of importation	Group of bulls: All	Evaluated sires	Deviating bulls
Canada	114	98	14
Germany	152	127	43
Italy	147	143	12
Netherlands	159	140	50
Sweden	15	9	4
US	45	42	9
Total bulls	632	559	132
Unique bulls	414	368	105

[1]All = international bulls with no national evaluation in January 1995 and a national evaluation with ≥80% reliability in February 1999; Evaluated sires = international bulls whose sires had national genetic evaluation data with ≥80% reliability in the importing country in January 1995; and Deviating bulls = international bulls whose January 1995 Interbull EBV differed from the conversion line by ≥0.25 genetic SD.

RESULTS AND DISCUSSION

As shown in Table 1, 632 foreign bulls received their initial genetic evaluation based on imported semen between January 1995 and February 1999. More than 100 bulls were evaluated based on imported semen during this period in Canada, Germany, Italy, and The Netherlands, but substantially fewer bulls had semen imported into Sweden and the US. Because semen of some bulls was imported into multiple countries, the number of unique bulls in the analysis was 414. Nearly 90% of these bulls had sires with national genetic evalu-

Table 2. Country of origin for bulls that received their first genetic evaluation based on imported semen between January 1995 and February 1999, by country of importation.

Country of importation	Country of origin				
	Canada	Germany	Italy	Netherlands	US
Canada				5	109
Germany	33		6	30	83
Italy	16	6		31	94
Netherlands	24	15	15		105
Sweden	1	1			13
US	34			11	

ation information in the importing country in January 1995. Approximately 20% of the bulls had MACE EBV that differed from the conversion line by more than 0.25 genetic SD. As shown in Table 2, bulls whose semen was imported by European countries were mainly from Canada and the US. Bulls whose semen was imported by Canada were primarily of US origin, and vice-versa, because Canada and the US began importing bull semen from Europe only recently.

The number of bulls used in calculating Wilmink conversion equations is shown in Table 3. Only conversions to and from Sweden were developed using data from less than 100 bulls. Conversions from North America to Europe were calculated with the gene flow (in the same direction as semen importation), whereas conversions from Europe to North America were calculated against the gene flow (in the opposite direction of semen importation) (6). Conversions between European countries were largely derived using data of third-country bulls, i.e., North American bulls whose semen was imported by multiple European countries. Although the resulting regression equations were not reciprocal, the same group of bulls was used to develop the Wilmink conversion equations in each direction (e.g., from Canada to Germany and from Germany to Canada).

The number of bulls used in calculating MACE conversion equations is shown for each pair of countries in Table 4. Because MACE conversions are developed from all bulls with progeny tested in the exporting country, regardless of whether or not these bulls have offspring in the importing country, the number of bulls is vastly larger than for Wilmink conversions. In contrast to Wilmink conversions, the groups of bulls differed according to the direction of conversion (e.g., bulls with progeny tested in Canada are used for Canada to Germany conversions, and bulls with progeny tested in Germany are used for Germany to Canada conversions). Although more bulls are used to calculate MACE conversions than Wilmink conversions, these extra bulls typically have progeny in only one country and, therefore, provide little additional information. In addition, the Wilmink method adjusts for the REL of bulls in the importing country (12).

Table 5 shows correlations between February 1999 national EBV in the importing country and January 1995 predicted EBV for all bulls evaluated based on imported semen during this period. Differences in correlations between the three prediction methods were not significant. For some countries, MACE EBV were more highly correlated with current national EBV than were conversions, but for other countries the reverse was true. Conclusions cannot be drawn from differences in correlations between importing countries, because these correlations can be highly influenced by factors such as selection intensity and number of progeny in the importing country. Weighted mean correlations (by number of bulls) across countries were nearly identical for all three methods. This result indicates that, although MACE is theoretically superior to regression-based conversion equations, due to inclusion of a larger number of bulls and accommodation of genotype by environment interaction, this theoretical advantage has not translated into significantly greater accuracy of predicted EBV in the six importing countries considered

Table 3. Number of bulls available for development of Wilmink conversion equations for each pair of countries.

Country	Germany	Italy	Netherlands	Sweden	US
Canada	113	133	117	77	347
Germany		118	151	48	197
Italy			121	70	215
Netherlands				56	202
Sweden					132

Table 4. Number of bulls available for development of multiple-trait, across-country evaluation conversion equations for each pair of countries.

Exporting country	Importing country: Canada	Germany	Italy	Netherlands	Sweden	US
Canada		866	872	871	867	810
Germany	1716		1725	1718	1726	1693
Italy	896	896		894	896	896
Netherlands	1653	1648	1654		1652	1634
Sweden	373	373	373	373		373
US	4880	4938	4961	4946	4928	

in this study. Although this result is disappointing, it is most likely not a limitation of the MACE methodology itself but, rather, a limitation of the data structure. Evaluated bulls with imported semen provide the only direct genetic connections between countries, and these bulls are used in both MACE and conversion analyses. Additional data from other related bulls (e.g., full sibs, half sibs, and cousins) can provide numerous weak, indirect connections, but the impact of these data are minimal compared with data from evaluated bulls with imported semen. It is important to recognize that MACE EBV and MACE conversions can be calculated for pairs of countries that share few or no common bulls; however, one must use extreme caution when genetic ties are so limited.

Figure 1 shows the proportion of foreign bulls that were in common when selection was based on 1999 national EBV and each of the 1995 predicted EBV. This graph confirms the results of the correlation analysis; no method was clearly superior with regard to selection of the correct foreign bulls. Figure 2 shows the proportion of international bulls that were in common when selection was based on each possible pair of 1995 prediction methods. As expected, Wilmink conversions and MACE conversions led to a very similar group of selected bulls. These regression-based methods force sire rankings to be identical in the importing and exporting countries, so differences in the selected group can only occur via a change in the relative number of bulls selected from each exporting country. With MACE EBV, however, bulls can rank differently in the importing and exporting countries, and this resulted in a much different group of selected bulls as compared with conversions. Figure 2 indicates that the equivalence in accuracy of MACE and converted EBV was not due to selection of an identical group of bulls but, rather, selection of different groups of bulls with a similar rate of errors in the selection process.

Table 5. Correlations (standard errors in italic) between February 1999 national EBV and January 1995 predicted EBV in each importing country using Wilmink conversions, multiple-trait, across-country evaluation (MACE) conversions, or MACE EBV.[1]

Importing country	Wilmink conversion: Milk	Fat	Protein	MACE Conversion: Milk	Fat	Protein	MACE EBV: Milk	Fat	Protein
Canada	0.73	0.83	0.78	0.74	0.83	0.78	0.73	0.81	0.77
	0.04	*0.03*	*0.04*	*0.04*	*0.03*	*0.04*	*0.04*	*0.03*	*0.04*
Germany	0.82	0.82	0.82	0.81	0.81	0.80	0.81	0.82	0.82
	0.03	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*	*0.03*
Italy	0.79	0.73	0.68	0.79	0.73	0.68	0.80	0.74	0.70
	0.03	*0.04*	*0.04*	*0.03*	*0.04*	*0.04*	*0.03*	*0.04*	*0.04*
Netherlands	0.87	0.82	0.84	0.87	0.82	0.85	0.88	0.83	0.86
	0.02	*0.03*	*0.02*	*0.02*	*0.03*	*0.02*	*0.02*	*0.02*	*0.02*
Sweden	0.77	0.78	0.72	0.74	0.79	0.70	0.72	0.79	0.66
	0.12	*0.12*	*0.14*	*0.13*	*0.12*	*0.15*	*0.14*	*0.12*	*0.16*
US	0.86	0.88	0.90	0.86	0.88	0.90	0.86	0.87	0.90
	0.04	*0.03*	*0.04*	*0.04*	*0.03*	*0.04*	*0.04*	*0.03*	*0.04*
Weighted[2] mean	0.81	0.80	0.79	0.81	0.80	0.79	0.81	0.80	0.79

[1]Results shown are for all international bulls that received their first genetic evaluation (with ≥80% reliability) based on imported semen between January 1995 and February 1999.

[2]Weights = Number of bulls from Table 1.

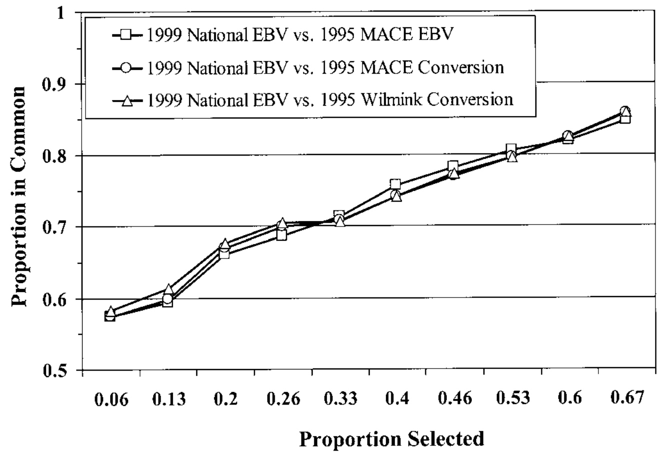

Figure 1. Proportion of selected bulls that were in common when selection was based on February 1999 national EBV and January 1995 predicted EBV in the importing countries using Wilmink conversions; multiple-trait, across-country evaluations (MACE) conversions; or MACE EBV. Results are averaged across traits and countries for all international bulls that received their first genetic evaluation (with ≥80% reliability) based on imported semen between January 1995 and February 1999.

In Table 6, correlations between February 1999 national EBV and January 1995 predicted EBV are reported for bulls whose sires had national genetic evaluation data in the importing country in January 1995. One might hypothesize that additional ancestor data in the importing country would improve performance of MACE relative to conversions, because MACE allows reranking of bulls based on in-country performance of their relatives. Although MACE EBV were slightly more accurate than converted EBV in this situation, this difference was not statistically significant.

In Table 7, correlations between February 1999 national EBV and January 1995 predicted EBV are reported for bulls whose MACE EBV differed by ≥0.25 genetic SD from the conversion line. Genotype by environment (country) interaction was predicted by MACE for this group of bulls. However, correlations between actual and predicted EBV were once again nearly equivalent for MACE and converted EBV.

CONCLUSIONS

In the present study, accuracy of January 1995 predictions of progeny performance for international bulls used in Canada, Germany, Italy, The Netherlands, Sweden, and the US were evaluated using February 1999 national EBV in these countries as a reference. Relative accuracy of MACE EBV was equivalent to that of Wilmink conversions and MACE conversions. Thus, although MACE represents the theoretically superior method for international comparisons, results from 632 bulls with semen imported into six countries indicate little or no advantage in accuracy. The lack of superiority of MACE relative to conversion equations is most likely not due to a deficiency in the methodology but, rather, due to limitations in the data structure. Evaluated bulls (and a few young sires) with imported semen provide the only direct genetic ties between countries.

Table 6. Correlations (standard errors in italic) between February 1999 national EBV and January 1995 predicted EBV in each importing country using Wilmink conversions, multiple-trait, across-country evaluation (MACE) conversions, or MACE EBV.[1]

Importing country	Method of prediction								
	Wilmink conversion			MACE Conversion			MACE EBV		
	Milk	Fat	Protein	Milk	Fat	Protein	Milk	Fat	Protein
Canada	0.73	0.80	0.77	0.73	0.80	0.77	0.72	0.78	0.76
	0.05	*0.04*	*0.04*	*0.05*	*0.04*	*0.04*	*0.05*	*0.04*	*0.04*
Germany	0.78	0.78	0.76	0.76	0.77	0.74	0.77	0.79	0.76
	0.03	*0.03*	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*	*0.03*	*0.04*
Italy	0.78	0.72	0.66	0.78	0.73	0.67	0.79	0.73	0.68
	0.03	*0.04*	*0.05*	*0.03*	*0.04*	*0.05*	*0.03*	*0.04*	*0.04*
Netherlands	0.86	0.80	0.83	0.86	0.81	0.83	0.87	0.83	0.85
	0.02	*0.03*	*0.03*	*0.02*	*0.03*	*0.03*	*0.02*	*0.03*	*0.02*
Sweden	0.85	0.70	0.51	0.85	0.72	0.54	0.82	0.72	0.52
	0.14	*0.21*	*0.28*	*0.13*	*0.21*	*0.27*	*0.16*	*0.21*	*0.28*
US	0.86	0.88	0.90	0.86	0.88	0.90	0.87	0.88	0.91
	0.04	*0.04*	*0.03*	*0.04*	*0.04*	*0.03*	*0.04*	*0.04*	*0.03*
Weighted[2] mean	0.80	0.78	0.76	0.79	0.78	0.76	0.80	0.78	0.76

[1]Results shown below are for international bulls whose sires had a national genetic evaluation with ≥80% reliability in the importing country in January 1995.

[2]Weights = The number of bulls from Table 1.

Table 7. Correlations (standard errors in italic) between February 1999 national EBV and January 1995 predicted EBV in each importing country using Wilmink conversions, multiple-trait, across-country evaluations (MACE) conversions, or MACE EBV.[1]

Importing country	Method of prediction								
	Wilmink conversion			MACE Conversion			MACE EBV		
	Milk	Fat	Protein	Milk	Fat	Protein	Milk	Fat	Protein
Canada	0.64	0.93	0.79	0.66	0.92	0.79	0.64	0.86	0.77
	0.18	*0.05*	*0.12*	*0.17*	*0.05*	*0.12*	*0.18*	*0.09*	*0.13*
Germany	0.80	0.83	0.80	0.79	0.82	0.79	0.79	0.86	0.84
	0.06	*0.05*	*0.06*	*0.06*	*0.05*	*0.06*	*0.06*	*0.04*	*0.05*
Italy	0.66	0.82	0.57	0.64	0.81	0.60	0.68	0.77	0.64
	0.19	*0.12*	*0.22*	*0.20*	*0.13*	*0.21*	*0.18*	*0.14*	*0.20*
Netherlands	0.82	0.74	0.78	0.82	0.75	0.78	0.84	0.78	0.82
	0.05	*0.07*	*0.06*	*0.05*	*0.06*	*0.06*	*0.04*	*0.06*	*0.05*
Sweden	0.23	0.77	0.77	0.01	0.84	0.84	–0.19	0.30	0.30
	0.48	*0.43*	*0.43*	*0.48*	*0.41*	*0.41*	*0.48*	*0.48*	*0.48*
US	0.95	0.95	0.95	0.96	0.95	0.95	0.96	0.88	0.95
	0.05	*0.05*	*0.06*	*0.04*	*0.06*	*0.06*	*0.04*	*0.12*	*0.08*
Weighted[2] mean	0.77	0.81	0.78	0.76	0.81	0.78	0.77	0.81	0.78

[1]Results shown below are for international bulls whose January 1995 Interbull EBV differed from the conversion line by ≥0.25 genetic SD.

[2]Weights = Number of bulls from Table 1.

Data from these bulls can be included in either MACE or conversion analyses. Although MACE provides a more flexible framework for including data of related bulls that can provide indirect ties, such bulls seem to have little influence relative to bulls with imported semen. The MACE methodology offers the advantage of providing international comparisons in situations in which few or no direct genetic ties (i.e., common sires) exist, but results should be used cautiously when genetic ties are extremely limited.

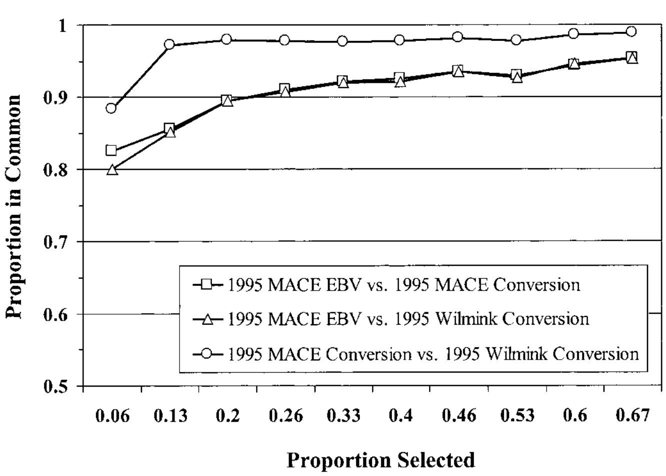

Figure 2. Proportion of selected bulls that were in common when selection was based on January 1995 predicted EBV in the importing countries using each possible pair of the following methods: Wilmink conversions; multiple-trait, across-country evaluation (MACE) conversions; or MACE EBV. Results are averaged across traits and countries for all international bulls that received their first genetic evaluation (with ≥80% reliability) based on imported semen between January 1995 and February 1999.

Because very few cows provide direct genetic links between countries, it is possible that international animal model evaluations with lactation records may also fail to provide a substantial improvement in accuracy relative to conversion equations calculated from data of bulls with imported semen. However, methods that utilize additional information regarding climate, herd management, or genetic background of the cow population, such as structural models for covariances (7), international herd-clustering models (11), and borderless evaluations (3), might escape some of the limitations in data structure associated with defining traits according to country boundaries.

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