National Index Correlations and Actual vs. Expected Use of Foreign Sires

***S. Toghiani* [1] *and P.M. VanRaden* [1]**
[1] *U.S. Department of Agriculture, Agricultural Research Service, Animal Genomics and Improvement Laboratory, Beltsville, MD 20705-2350, USA*

Abstract

Differing selection indexes, genetic correlations < 1.0, and missing traits each cause reranking of the same bulls in different countries. To quantify, correlations were estimated using selection indexes from 15 major countries as of 2020. When different national indexes were used to compute rankings on the same EBV scale, most correlations were ≥ 0.80 and many were ≥ 0.90. Correlations were even higher when 1 index was applied to EBVs on all 15 scales. Thus, index definitions generally caused more reranking than EBV differences across scales. Foreign bulls were >80% of the top bulls in nearly all countries but often sired <50% of domestic cows. Reasons might include health restrictions, higher prices, lack of information, lack of technician service, or protectionism. Foreign bull use in each country is now documented in a web query. Because index correlations are high, many countries can improve genetic progress by using domestic bulls less and foreign bulls much more.

Key words: importation, protectionism, trade, semen, genetic evaluation

Introduction

Dairy producers can choose the best available bulls globally to increase progress locally. Previous research developed methods to rank foreign bulls when some or all traits are missing (Mark et al., 2006a & 2006b; Torsell et al., 2007), compared national selection indexes (Miglior et al., 2005), proposed a global index (Powell and VanRaden, 2001), and summarized foreign sire use (Dürr and Jakobsen, 2009) before genomic selection was common (de Roos et al., 2009). New research should revise, compare, and implement international selection with the much larger numbers of traits now available.

National bull rankings differ due to both index differences and genetic correlations < 1.0 between countries. Current goals were to determine the actual use of foreign sires, the optimal use, and how much the use is affected by genetic correlations, the national selection index, national availability of traits, and methods to fill missing traits.

Materials and Methods

Evaluations on all country scales from the December 2019 routine MACE files for all proven Holsteins born 2005-2013 were used to obtain top bull lists. Correlations among indexes were estimated using a subset of 1,847 bulls that had at least 200 daughters with yield records on USA scale and born between 2005-2010 to ensure that reliable EBVs were available for nearly all traits. The EBVs for each trait on each country scale were standardized by dividing by one standard deviation (SD) so that relative value formulas from each of the 15 national indexes in Table 1 could be applied.

Before standardization, missing EBVs from some countries for health, reproduction, and durability traits were set to the mean of available EBVs grouped by birth year and trait. Some national indexes include traits classified as “other” in Table 1 that could not be standardized or used because no MACE EBVs are available for those traits. The missing EBVs in “other” traits can be estimated for genomic selection from reference population phenotypes in the importing country and genotypes for the bulls being exported. Actual index rankings computed by national evaluation centers may differ from those computed here due to "other" traits in the index, use of national rather than MACE EBVs for some bulls, differing estimates of SD, or different ways to fill missing EBVs such as parent average or multi-trait methods. An additional analysis of NM$ on USA scale estimated sire country, MGS country, and birth year effects for all 6,777 global AI bulls born since 2010 to compare the overall merit of ancestors from each country.

Foreign sire use by country

Recent use of domestic and foreign sires in each of 30 countries was documented from daughter counts in the MACE file for production traits. Each bull's origin was determined using the country code in the bull's ID, for example with USA or 840 in the ID indicating the source even if sold as an embryo or young bull to another country. Bulls from DNK, FIN, and SWE were combined into source DFS. Currently CDCB counts the number of each country's bulls in the top 100 for each trait on each country scale: https://queries.uscdcb.com/eval/summary/top100.cfm?t100_tbl=hdHOP.

The high rankings of foreign bulls for important individual traits might make us expect more use of foreign bulls in many countries, especially in Europe. Foreign sires should also be used more in countries with smaller populations. The above web report does not compare overall merit on each country scale but now reports domestic and foreign market shares for AI bulls from each country: https://queries.uscdcb.com/eval/summary/top100.cfm?t100_tbl=fsuHOL

Finally, the optimal use of foreign bulls was estimated from the proportion of each country's bulls in the top 100 or top 1000 ranked using that country's index and scale. The top 100 could sire the elite breeding stock whereas the top 1000 could sire the commercial cows.

Results & Discussion

The correlations between each national index computed on USA scale in Table 2 range from 0.31 for Ireland with Japan to 0.98 for Germany with Switzerland. Most correlations were ≥ 0.80, and 27 of the 105 pairs were ≥ 0.90. The correlations combining traits on different scales using the same USA index in Table 3 ranged from 0.69 for Australia with both Netherlands and Italy to 0.97 for USA with Canada or for Italy with Spain. In Table 3, correlations were ≥ 0.90 for 54 of the 105 pairs, indicating less impact from scale differences and genetic correlations than from index definitions.

The combined effects of using both the foreign scale and its index compared to USA scale and NM$ are in Table 4. This was further expanded in Table 5 to show correlations for each country combining the EBVs on its scale using the relative values in its index to provide a broad picture of how much total reranking of Holstein bulls occurs across countries due to both index and scale.

Foreign sire use by country

Recent use of foreign sires in most countries was less than the expected use computed from the top bull rankings. Table 6 presents the expected distribution of top 100 ranking Holstein bulls born between 2005-2013 across countries each using their own scale and index. In most countries about 70% of top sires were from USA and nearly 10% each from Canada and Netherlands. The other countries provided the remaining 10% of top bulls except with somewhat higher percentages on their own scale. In the top 1000 rankings, about 60% instead of 70% were USA sires whereas Scandinavian, German, French, and Italian sires increased by a total of about 10% of the top lists.

Actual percentages of milk-recorded cows with foreign sires in Table 7 were lowest in New Zealand (2%) and Israel (5%) and highest in Spain and Great Britain (73%). Most countries use foreign bulls for elite matings but not as much for general matings in the commercial cow population (<50%). Most should use more foreign sires because those dominate the top bull lists (>80%) in nearly all countries. Actual use may be limited by trade restrictions, near monopolies for AI in some countries, or higher prices to use the best bulls. Increased use of foreign bulls can reduce inbreeding and improve accuracy and genetic variance in the importing country (Cao et al., 2021).

Conclusions

Bull rankings differ across countries more from different selection goals than from genotype by environment interaction or missing traits. Countries that use foreign bulls only as sires of their AI bulls but not for the general cow population always remain at least 1 generation behind. In most countries, foreign sires are the better choice to maximize genetic progress.

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Table 1. Relative values for traits or trait groups[1] in national indexes for Holstein breed.

		Relative value (%)													
Country	Index	Year	milk	fat	prot	fert	scs	mas	calv	long	flc	ouc	ocs	size	other
AUS	BPI	2019	-8	25	22	13	-10	—	—	—	—	—	12	-3	7
CAN	LPI	2019	—	16	24	13.4	-3.3	3.3	—	8	11.2	14.8	—	6	—
FRA	GDM	2014	-9	4	27	20	-12	3	—	—	12.5	—	10	—	2.5
DEU	RZG	2019	—	14.8	30.2	10	-7	—	3	20	4.5	6	4.5	—	—
IRL	EBI	2018	-8.9	7	17.9	23	-2	1	5	11	—	—	—	-6	18.5
ISR	PD11	2011	—	15	41	16	-13	—	3	8	—	—	—	—	4
ITA	PFT	2013	-2.5	9	37.5	10	-10	—	—	8	6	13	4	—	—
JPN	NTP	2010	—	19.4	52.6	—	-4	—	—	—	3.6	20.4	—	—	—
NLD	NVI	2018	—	10	19	16	-12	—	5	12	16	5	—	-5	—
NZL	BW	2019	-13	20	18	13	-7	—	—	11	—	—	—	-11	7
DFS	NTM	2018	-5	11	14	12.5	—	14	12.8	4.6	3	3.6	—	—	19
ESP	ICO	2013	22	5	30	3	-3	—	—	19	9	9	—	—	—
CHE	ISEL	2013	-5.6	9.4	29.9	15	-8	—	—	10	5	5	7.5	-2.5	2
GBR	PLI	2018	-8.3	9.5	16.6	15.3	-13.7	—	1.6	15.1	8.1	5	—	-6.8	—
USA	NM$	2018	-1	27	17	10	-4	1	5	19	3	7	—	-5	1.3

[1] prot: protein; fert: fertility index; scs: somatic cell score; mas: clinical mastitis; calv: calving ability index; long: longevity; ocs: overall conformation score; flc: feet & legs composition; ouc; overall udder composition; size: body weight composite; other: workability in BPI index; milking speed in GDM index; milking speed, milking temperament, carcass weight, cull cow weight, carcass conformation, carcass fat, lameness, gestation length in EBI index; lactation persistency in PD11 index; Body condition score in BW index; Growth, General health, milking, claw health, temperament, young stock survival in NTM index; milking speed in ISEL index; health trait index including ketosis, retained placenta, metritis, displaced abomasum, and milk fever in NM$ index.

Table 1. Correlations between global indices[1] applying each country's relative values to USA scale data for 1,847 Holstein sires[2]

	AUS	CAN	CHE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	JPN	NLD	NZL	USA
AUS	1.00	0.89	0.90	0.89	0.83	0.72	0.80	0.72	0.62	0.89	0.89	0.82	0.80	0.79	0.90
CAN	0.89	1.00	0.92	0.91	0.81	0.86	0.87	0.66	0.53	0.82	0.96	0.88	0.82	0.59	0.83
CHE	0.90	0.92	1.00	0.98	0.80	0.83	0.91	0.87	0.77	0.93	0.96	0.78	0.94	0.81	0.93
DEU	0.89	0.91	0.98	1.00	0.81	0.89	0.82	0.82	0.74	0.96	0.96	0.83	0.91	0.80	0.96
DFS	0.72	0.73	0.75	0.76	1.00	0.68	0.69	0.63	0.75	0.76	0.69	0.60	0.72	0.70	0.80
ESP	0.72	0.86	0.83	0.89	0.76	1.00	0.64	0.53	0.47	0.86	0.90	0.90	0.71	0.52	0.78
FRA	0.80	0.87	0.91	0.82	0.70	0.64	1.00	0.81	0.67	0.74	0.85	0.62	0.90	0.65	0.74
GBR	0.72	0.66	0.87	0.82	0.59	0.53	0.81	1.00	0.90	0.76	0.73	0.41	0.95	0.90	0.86
IRL	0.62	0.53	0.77	0.74	0.67	0.47	0.67	0.90	1.00	0.75	0.59	0.31	0.84	0.91	0.81
ISR	0.89	0.82	0.93	0.96	0.83	0.86	0.74	0.76	0.75	1.00	0.91	0.82	0.84	0.83	0.93
ITA	0.89	0.96	0.96	0.96	0.77	0.90	0.85	0.73	0.59	0.91	1.00	0.90	0.85	0.67	0.87
JPN	0.82	0.88	0.78	0.83	0.75	0.90	0.62	0.41	0.31	0.82	0.90	1.00	0.59	0.47	0.73
NLD	0.80	0.82	0.94	0.91	0.70	0.71	0.90	0.95	0.84	0.84	0.85	0.59	1.00	0.84	0.90
NZL	0.79	0.59	0.81	0.80	0.71	0.52	0.65	0.90	0.91	0.83	0.67	0.47	0.84	1.00	0.91
USA	0.90	0.83	0.93	0.96	0.84	0.78	0.74	0.86	0.81	0.93	0.87	0.73	0.90	0.91	1.00

[1] AUS: Australia (BPI index), CAN: Canada (LPI index), CHE: Switzerland (ISEL index), DEU: Germany (RZG), DFS: Denmark, Finland, and Sweden (NTM index), ESP: Spain (ICO index), FRA: France (GDM index), GBR: Great Britain (PLI index), IRL: Ireland (EBI index), ISR: Israel (PD11 index), ITA: Italy (PFT index), JPN: Japan (NTP index), NLD: Netherlands (NVI index), NZL: New Zealand (BW index), USA: United States (NM$ index)
[2] Sires born between 2005-2010 with at least 200 USA yield daughters

Table 2. Correlations among evaluations on different country scales[1] using the same index (relative values in USA NM$) for 1,847 Holstein sires[2]

	AUS	CAN	CHE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	JPN	NLD	NZL	USA
AUS	1.00	0.74	0.72	0.74	0.74	0.74	0.84	0.71	0.82	0.76	0.69	0.79	0.69	0.86	0.71
CAN	0.74	1.00	0.92	0.94	0.96	0.96	0.85	0.94	0.92	0.93	0.93	0.80	0.92	0.80	0.97
CHE	0.72	0.92	1.00	0.95	0.94	0.94	0.88	0.94	0.91	0.91	0.94	0.81	0.95	0.83	0.91
DEU	0.74	0.94	0.95	1.00	0.94	0.95	0.90	0.91	0.89	0.92	0.92	0.85	0.92	0.79	0.93
DFS	0.74	0.96	0.94	0.94	1.00	0.96	0.87	0.95	0.92	0.93	0.94	0.83	0.95	0.83	0.94
ESP	0.74	0.96	0.94	0.95	0.96	1.00	0.87	0.95	0.91	0.94	0.97	0.82	0.94	0.81	0.96
FRA	0.84	0.85	0.88	0.90	0.87	0.87	1.00	0.81	0.86	0.88	0.85	0.92	0.85	0.80	0.84
GBR	0.71	0.94	0.94	0.91	0.95	0.95	0.81	1.00	0.92	0.91	0.92	0.76	0.94	0.84	0.93
IRL	0.82	0.92	0.91	0.89	0.92	0.91	0.86	0.92	1.00	0.89	0.88	0.77	0.90	0.93	0.89
ISR	0.76	0.93	0.91	0.92	0.93	0.94	0.88	0.91	0.89	1.00	0.93	0.80	0.94	0.83	0.94
ITA	0.69	0.93	0.94	0.92	0.94	0.97	0.85	0.92	0.88	0.93	1.00	0.79	0.94	0.79	0.93
JPN	0.79	0.80	0.81	0.85	0.83	0.82	0.92	0.76	0.77	0.80	0.79	1.00	0.79	0.73	0.78
NLD	0.69	0.92	0.95	0.92	0.95	0.94	0.85	0.94	0.90	0.94	0.94	0.79	1.00	0.81	0.92
NZL	0.86	0.80	0.83	0.79	0.83	0.81	0.80	0.84	0.93	0.83	0.79	0.73	0.81	1.00	0.78
USA	0.71	0.97	0.91	0.93	0.94	0.96	0.84	0.93	0.89	0.94	0.93	0.78	0.92	0.78	1.00

[1] AUS: Australia (BPI index), CAN: Canada (LPI index), CHE: Switzerland (ISEL index), DEU: Germany (RZG), DFS: Denmark, Finland, and Sweden (NTM index), ESP: Spain (ICO index), FRA: France (GDM index), GBR: Great Britain (PLI index), IRL: Ireland (EBI index), ISR: Israel (PD11 index), ITA: Italy (PFT index), JPN: Japan (NTP index), NLD: Netherlands (NVI index), NZL: New Zealand (BW index), USA: United States (NM$ index)
[2] Sires born between 2005-2010 with at least 200 USA yield daughters

Table 4. Correlations using either the scale, the index, or both for each different country compared with USA scale and NM$ index for 1,847 Holstein sires born between 2005-2010 with at least 200 USA yield daughters

	AUS	CAN	CHE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	JPN	NLD	NZL	USA
Index	0.90	0.83	0.93	0.96	0.84	0.78	0.74	0.86	0.81	0.93	0.87	0.73	0.90	0.91	1.00
Scale	0.71	0.97	0.91	0.93	0.94	0.96	0.84	0.93	0.89	0.94	0.93	0.78	0.92	0.78	1.00
Both	0.72	0.80	0.81	0.90	0.78	0.78	0.67	0.76	0.72	0.88	0.80	0.72	0.82	0.75	1.00

Table 5. Correlations among evaluations for 1,847 Holstein sires[2] combined using both the index[1] and EBV scale of each country

		Index and scale														
		AUS	**CAN**	**CHE**	**DEU**	**DFS**	**ESP**	**FRA**	**GBR**	**IRL**	**ISR**	**ITA**	**JPN**	**NLD**	**NZL**	**USA**
Index and scale	**AUS**	1.00	0.74	0.71	0.72	0.70	0.56	0.64	0.56	0.57	0.75	0.71	0.72	0.60	0.77	0.72
	CAN	0.74	1.00	0.87	0.87	0.80	0.82	0.80	0.63	0.57	0.79	0.90	0.86	0.76	0.60	0.80
	CHE	0.71	0.87	1.00	0.91	0.72	0.78	0.91	0.76	0.68	0.85	0.91	0.80	0.86	0.72	0.81
	DEU	0.72	0.87	0.91	1.00	0.75	0.88	0.78	0.73	0.66	0.92	0.90	0.85	0.85	0.70	0.90
	DFS	0.58	0.71	0.65	0.65	1.00	0.60	0.58	0.56	0.66	0.65	0.61	0.60	0.64	0.65	0.74
	ESP	0.56	0.82	0.78	0.88	0.70	1.00	0.64	0.50	0.46	0.83	0.83	0.86	0.69	0.47	0.78
	FRA	0.64	0.80	0.91	0.78	0.62	0.64	1.00	0.73	0.62	0.74	0.86	0.66	0.84	0.62	0.67
	GBR	0.56	0.63	0.76	0.73	0.53	0.50	0.73	1.00	0.88	0.71	0.73	0.44	0.90	0.81	0.76
	IRL	0.57	0.57	0.68	0.66	0.63	0.46	0.62	0.88	1.00	0.69	0.63	0.39	0.77	0.85	0.72
	ISR	0.75	0.79	0.85	0.92	0.74	0.83	0.74	0.71	0.69	1.00	0.87	0.80	0.82	0.73	0.88
	ITA	0.71	0.90	0.91	0.90	0.69	0.83	0.86	0.73	0.63	0.87	1.00	0.85	0.84	0.66	0.80
	JPN	0.72	0.86	0.80	0.85	0.75	0.86	0.66	0.44	0.39	0.80	0.85	1.00	0.61	0.54	0.72
	NLD	0.60	0.76	0.86	0.85	0.63	0.69	0.84	0.90	0.77	0.82	0.84	0.61	1.00	0.74	0.82
	NZL	0.77	0.60	0.72	0.70	0.69	0.47	0.62	0.81	0.85	0.73	0.66	0.54	0.74	1.00	0.75
	USA	0.72	0.80	0.81	0.90	0.78	0.78	0.67	0.76	0.72	0.88	0.80	0.72	0.82	0.75	1.00

[1] AUS: Australia (BPI index), CAN: Canada (LPI index), CHE: Switzerland (ISEL index), DEU: Germany (RZG), DFS: Denmark, Finland, and Sweden (NTM index), ESP: Spain (ICO index), FRA: France (GDM index), GBR: Great Britain (PLI index), IRL: Ireland (EBI index), ISR: Israel (PD11 index), ITA: Italy (PFT index), JPN: Japan (NTP index), NLD: Netherlands (NVI index), NZL: New Zealand (BW index), USA: United States (NM$ index)
[2] Sires born between 2005-2010 with at least 200 USA yield daughters

Table 6. The origin of the top 100 proven Holstein bulls[1] on each country's scale using that country's index

Country selection indexes and scale	Bull's origin country													
	AUS	**CAN**	**DEU**	**DFS**	**FRA**	**GBR**	**IRL**	**ISR**	**ITA**	**JPN**	**NLD**	**NZL**	**USA**	**Other[2]**
AUS	4	9	4	2	4	2	0	0	0	0	9	5	60	1
CAN	0	17	0	0	1	0	0	0	0	0	7	0	75	0
CHE	0	12	8	2	1	0	0	0	1	0	6	0	70	0
DEU	0	8	6	1	1	0	0	0	0	0	7	0	77	0
DFS	0	10	3	12	0	0	0	0	0	0	8	0	67	0
ESP	0	8	8	2	1	0	0	0	2	0	7	0	72	0
FRA	0	13	2	1	2	0	0	0	0	0	4	0	78	0
GBR	0	8	0	2	0	0	0	0	0	0	10	0	80	0
IRL	0	4	0	1	0	0	19	0	0	0	9	27	40	0
ISR	0	2	5	2	1	1	0	9	0	0	5	0	75	0
ITA	0	12	2	0	2	0	0	0	0	0	3	0	81	0
JPN	0	8	7	2	3	1	0	0	1	2	8	0	68	0
NLD	0	10	1	0	0	0	0	0	0	0	13	0	76	0
NZL	0	3	0	0	0	0	0	0	0	0	3	76	18	0
USA	0	4	0	0	1	1	0	0	0	0	2	0	92	0

[1] Bulls born between 2005-2013 without restriction on number of daughters and herds
[2] Others: bull originated from Poland (POL)

Table 7. Actual percentages of foreign sire use and expected use based on the top 100 or top 1000 proven Holstein sires in each country's ranking

Foreign%	AUS	CAN	CHE	DEU	DFS	ESP	FRA	GBR	IRL	ISR	ITA	JPN	NLD	NZL	USA
Actual[1]	60	56	38	51	15	73	13	73	15	5	52	39	18	2	8
Expected[2]	96	83	100	94	88	100	98	100	81	91	100	98	87	24	8
Expected[3]	98	88	100	91	88	99	95	99	86	95	98	96	92	54	23

[1] Percentages of milk-recorded cows with foreign sires born since 2008.
[2] Percentages of top 100 proven sires born 2005-2013 that are foreign.
[3] Percentages of top 1000 proven sires born 2005-2013 that are foreign.