Genetic improvement: a major component of increased dairy farm profitability

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Abstract

Selection objectives worldwide have changed drastically in most countries in the last decade. As a consequence, most countries are reversing undesirable genetic trends in their bull populations. An improvement for longevity, SCS and fertility is evident across the major dairy countries in the most recent years, while genetic progress for production has continued at about the same rate as before. The analysis of Canadian cow trends confirms what has been observed in the bull population. Additionally, it becomes evident from a closer analysis of those trends that the availability of genetic evaluations for functional traits and their inclusion in selection indices have a direct impact on population genetic trends. For traits which have been selected for a long time, such as fat and protein yields, genetic improvement accounted for 60-70% of total phenotypic change. The over-all net value of genetic improvement to the Canadian dairy industry was estimated at $209 million per year.

Keywords: Selection index, genetic progress, genetic trends

Introduction

Genetic improvement has been a major force, if not the major one, for making advances in dairy cattle profitability during the last few decades. Improvement has first been for production and conformation traits, except in some Scandinavian countries where an early focus was also placed on fertility and disease resistance. In the last decade, however, selection objectives in many countries have been adjusted to give more emphasis to health, fertility and longevity, in addition to production and conformation. This was made possible by an increased effort in the collection of data for the corresponding traits in on-farm recording programs. The objective of this article is to review the selection objectives that are now in use in the Holstein breed among Interbull member countries, and to report and compare the genetic trends achieved for key economic traits over the last 10 years for successive groups of bulls that entered progeny testing and are now proven. Finally, Canada was used as a case study to examine the impact of genetic improvement at the level of the cow population and to measure its economic significance for the dairy industry.

Selection Indices Worldwide

It is well known that selection for milk production per lactation has a negative effect on reproduction and health, as highly productive animals often find themselves in a negative energy balance in the first part of their lactation. This does not mean that selection for production traits should cease. These traits still have a major impact on the revenue of each farm, and are still worth improving. However, selection for production per lactation should be accompanied by selection for fertility and health in order to counteract the negative genetic correlations that exist between these two groups of traits. This is especially true because the marginal cost of decreased fertility becomes higher and higher as pregnancy rate decreases. Therefore, the emphasis on health, fertility and longevity has increased in the selection indices of most countries. Despite this, there are considerable differences among the selection indices of Interbull countries. Table 1 presents the relative emphasis (%) on various traits included in 18 different selection indices worldwide.

Table 1. Relative emphasis (%) of various traits in national selection indices worldwide for Holsteins.

	Protein kg	Fat kg	Milk kg	Type	Longevity	Udder Health	Fertility	Others
Australia - APR	28	7	-12		17	8	19	10
Belgium (Walloon) - V€G	29	9	-10	24	23	5		
Canada - LPI	31	20		27	7	5	10	
France - ISU	40	10		13	13	13	13	
Germany - RZG	36	9		15	20	7	10	3
Great Britain - PLI	22	12	-11	4	21	11	19	
Ireland - EBI	21	4	-10		8	3	25	29
Israel - PD11	42	15			8	13	16	6
Italy - PFT	39	2	-8	23	8	10	10	
Japan - NTP	53	19		24		4		
Netherlands - NVI	14	9	-3	28	11	14	14	5
New Zealand - BW	40	12	-15		6	7	8	13
Nordic Countries - TMI	21	5	-5	11	5	17	13	19
South Africa - BVI	26	26		45		3		
Spain - ICO	30	5	-22	29	8	3	3	
Switzerland - ISEL	34	11		20	10	8	15	2
United States - NM	16	19		17	22	10	11	5
United States - TPI	27	16		29	9	5	11	3
Average	***31%***	***12%***	***5%***	***17%***	***11%***	***8%***	***11%***	***5%***

Emphasis for production traits, for example, varies from 72% in Japan to 26% in the Netherlands. These differences might be explained by differences from one country to the next in milk and component prices, and in input and service costs. They could also result from differences in production environments (for example grazing versus non-grazing) or in national genetic improvement policies. From a global perspective, large differences in the definition of selection objectives could be beneficial, since they are likely to lead to more genetically diverse breed populations than if all countries had the same selection objective. History has shown that given the long-term nature of genetic improvement, countries or breeding companies can occasionally launch themselves in genetic directions that later are found not to be optimal, in which case the availability of diverse genetic material from other sources makes adjustments possible and provides a kind of policy insurance. More genetic diversity also means more global genetic variation, a necessary ingredient for effective selection.

The magnitude of change in indices over time is also of interest. Table 2 shows the changes in relative emphasis on production traits in the selection indices of four countries which were taken as an example. The Netherlands show the greatest change (100% emphasis on production in 1995 to 26% in 2012), followed by Ireland (100% to 35% in the same time period). Canada and US register smaller changes (20 to 24 percentage points).

Table 2. Changes in relative emphasis on production in selection indices from four countries

	Canada	Ireland	Netherlands	United States*
1995	71%	100%	100%	67%
2000	60%	71%	82%	57%
2005	57%	69%	58%	54%
2012	51%	35%	26%	43%

*TPI index

Analysis of Bull Genetic Trends from Major Dairy Countries

MACE EBVs from Interbull April 2012 run were used for this part of the analysis. Five major traits were considered: Protein kg (indicator of production), Overall Udder (indicator of conformation), Longevity, SCS (indicator of udder health) and Calving to First Service (indicator of fertility). MACE EBVs on the Canadian scale were standardized to SD units and only bulls born from 1997 to 2006 were kept. The country of origin of each bull was assumed to be the country where the bull had the largest number of daughters. Major dairy countries were defined as those with at least 200 bulls tested per year. Additionally, Ireland, which only tests 25 to 65 bulls per year, was added to the analysis. Genetic trends for bulls born in 1997-06 were plotted for the five traits in Figures 1 to 5. The average EBV of bulls born in the most recent years (2005-06) was computed and plotted for each trait and country. In Figure 6, each trait was given an equal weight. In Figure 7, each trait was given a weight corresponding to the average selection index weight for all countries in Table 1, after excluding “other” traits. This latter approach resulted in the following weights: Production 49%, Type 18%, Longevity 12%, Udder Health 9%, Fertility 12%. The annual genetic change in the genetic level of bulls from the last 5 complete years of birth (2002-06) is plotted in Figure 8, by country and trait. Table 3 shows the annual genetic progress for bulls born in 1997-'01 and in 2002-'06, averaged across the 10 countries, with the corresponding standard deviations.

Table 3. Average (and SD) annual genetic progress for bulls born in 1997-'01 and 2002-'06 (expressed in SD units, higher values are desirable for all traits).

		Protein kg	Overall Udder	Longevity	SCS	Fertility
2002-06	Average	.081	.176	.194	.141	.063
	SD	.034	.069	.063	.032	.042
1997-01	Average	.091	.055	.039	-.003	-.075
	SD	.079	.043	.086	.048	.108

The trends observed in Figures 1 to 5 correspond to the average estimated genetic merit of bulls that entered progeny testing programs each year in various countries. These trends therefore reflect the efforts of AI organizations in bull selection. The trends are by birth year. They are based on bulls that had a proof by April 2012 and now have a relatively accurate EBV. It is important to note that the selection that led to these trends was made without the help of genomics, since the bull groups examined here were born from 1997 to 2006, i.e. before genomics could guide their selection. Also, the average genetic level of progeny tested bulls is not necessarily the same as the average genetic contribution of sires to the genetic level of the cow population, since AI organizations control which bulls they put back into service and producers decide which of these bulls they want to use in their herds. However, previous studies have shown that genetic trends in the cow population generally reflect those in bull selection. Looking at all ten countries together, the major change in terms of the average EBV of bulls in the Holstein breed has been a reversal from an unfavorable trend in somatic cell score, fertility and longevity to a favorable one (Table 3). This demonstrates that AI companies, as a group, have responded to the change in national selection objectives and have selected bulls which indeed were superior to previous groups for these traits when proven. The unfavorable increase in somatic cell score EBV stopped with bulls born around 1998, soon after the introduction of proofs for this trait in several countries. This gave way to a slow decline in average SCS EBV until about birth year 2003, and a more rapid and favorable decline between 2004 and 2008. The decline in longevity EBV was reversed with bulls born in 2000, and a fairly rapid increase has been achieved since then in most countries. The situation for fertility traits, as illustrated by the trend in EBV for calving to first service interval, is fairly similar to that of longevity EBV, with a decrease in most countries for bulls born until 2002, at which time the EBV of progeny tested bulls reached a plateau, and later increased slightly. It is important to point out that several environmental causes, most notably herd size, cow comfort, reproduction management, have been involved in the decline in fertility, therefore reversing the genetic decline does not necessarily mean that the phenotypic decline will be reversed. However, from a genetic standpoint, the positive trend in fertility of successive bull groups in the last few years should be considered excellent news.

One remarkable fact is that these positive trends for functional traits over the last few years were achieved with no significant reduction in trends for production traits, and while more rapid improvement for some type traits, such as udder conformation, was taking place. Generally, progress for one trait must be carried out at the expense of the others, unless selection methods become more efficient. One must therefore conclude that AI organizations worldwide have practiced more rigorous selection in the last 5 years than ever before, on the basis of traditional selection methods. Now that genomic selection is in use, one can expect even higher rates of progress in the genetic level of selected bulls, particularly for low heritability traits like fertility and longevity, where the increase in prediction accuracy is proportionally higher compared to what was achievable with parent averages. An analysis of trends in the G-MACE EBV of bulls born in Interbull member countries in 2009 and thereafter would be particularly useful to demonstrate this point. This analysis can be done if G-MACE becomes an official service provided by Interbull.

Although there is a wide range of selection objectives across countries, individual trends in bull EBV for the 10 countries tended to move in the same direction for each trait. One reason for this could be that the trends observed here reflect past selection objectives, which were closer than they are today. Another could be that AI organizations tend to select from the same popular sire families and in such a way that their realized objectives are closer than national selection indices would imply. The only real exceptions to this appear to be New Zealand and Ireland, where grazing conditions imply strong selection for calving to first service interval. As a result, the genetic level of progeny tested bulls for CFS is higher in these countries than elsewhere and has evolved differently. On the other hand, their genetic levels for protein yield and udder conformation tend to be lower.

A case study: Canada

Canada was used as case study to examine the genetic trends for the cow population, in addition to those of progeny tested bulls, and their economic impact on the industry. Table 4 shows the change in relative emphasis for various traits in the Canadian LPI over time. This helps explain the changes in genetic trends that occurred for some of these traits.

Table 4. Changes in relative emphasis (%) on various traits in Canadian LPI over time

	Protein	Fat	Type	Herd Life	Udder Health	Fertility
1991	33	27	40			
1993	44	16	40			
1998	49	11	40			
2001	43	14	30	8	5	
2005	32	22	29	7	5	5
2008	31	20	27	7	5	10

Cow evaluations from the April 2012 CDN official run were used for this part of the analysis. These cow evaluations reflect genomic evaluations whereas the MACE EBV reflect only the traditional evaluations. Additionally parent averages (PA) for females born in 2010 and 2011 were used for the analysis, and 'converted' to cow EBV using the average difference between PA and EBV from 2005 to 2009. This has allowed an analysis of trends for the most recent years. Figure 9 shows cow genetic trends for milk, fat and protein yields, and for mammary system (the Canadian trait for overall udder). Figure 10 shows cow genetic trends for SCS and Direct Herd Life (the Canadian trait for functional longevity). This plot also includes the year when genetic evaluation for SCS (1995) and Herd Life (1996) became official in Canada, and the year when both traits were included in the Canadian selection index (LPI). Figure 11 shows cow genetic trends for two female fertility traits in Canada, interval from calving to first service (genetic evaluation started in 2004) and interval from first service to conception (genetic evaluation started in 2008).

Generally, trends in the EBV of Canadian Holstein cows followed those for bulls. Cow genetic trends for SCS, longevity and CFS improved markedly over the last 5 years, becoming favorable instead of unfavorable, this despite more rapid genetic improvement in protein yield, fat yield, udder conformation and feet and legs than in the previous 5 years (Figure 12). It is very interesting to note how the timing of availability of genetic evaluations for those traits coincides with the change in genetic trend. It is also clear that trends change direction once those traits are included in the Canadian LPI.

Trends for protein and fat yields accounted for 60-70% of total phenotypic change for these traits over the last 20 years in the Canadian Holstein breed (Figure 13). Based on the estimated economic value of production, conformation, health, fertility and longevity traits to the Canadian dairy producer, and accounting for the fact that genetic change is cumulative, the over-all net value of genetic improvement to the Canadian dairy industry was estimated at $209 million per year, after taking all input costs into account, including breeding costs. This represents about 6% of the total farm cash receipts of $5.5 billion for dairy products in Canada in 2010, and is very likely a large proportion of total farm income (over all commodities, farm income in Canada was 6.7% of total farm cash receipts). With the use of genomics, these net benefits from genetic improvement could increase even more, mostly as a result of a reduction in generation interval.

Conclusions

The average EBV of bulls born between 2001 and 2006 for SCS, longevity and CFS increased over the last 5 years in almost all of the 10 countries included in this study, instead of decreasing as in previous years. This indicates that AI organizations have taken action to reflect the increased emphasis on functional traits in national selection objectives. These advances have been achieved without a reduction in the rate of progress for key production and conformation traits, and without the use of genomic selection, since that new tool was not yet available. Canadian data shows that genetic trends in the cow population roughly follow those of successive bull groups, and that genetic improvement has a considerable economic impact for the dairy industry. With genomics, one can expect this impact to become even larger, particularly through improvements for functional traits. It is essential to stress that on-farm recording is an essential component of dairy cattle genetic improvement, and that genomics does not change this situation. If anything, the efficient use of genomics for the selection of novel traits will require collection of accurate data on a very large scale.

Figure 1. Bull genetic trends on the Canadian scale for protein yield (expressed in SD units)

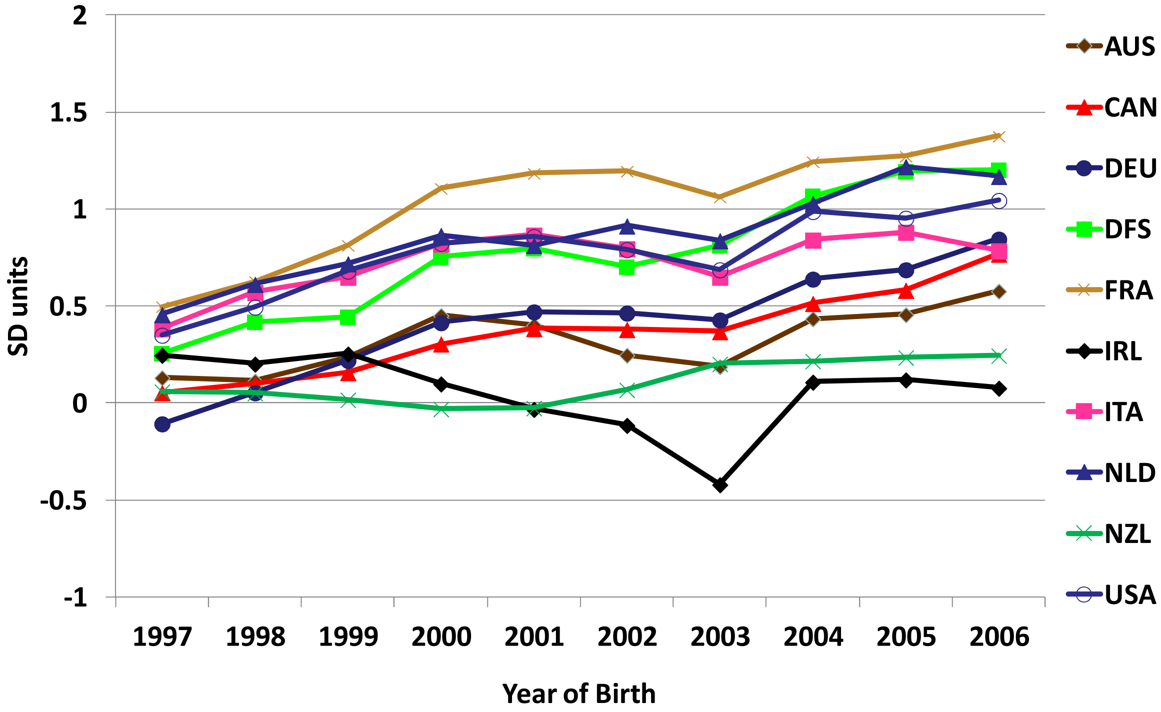


Figure 2. Bull genetic trends on the Canadian scale for overall udder (expressed in SD units)

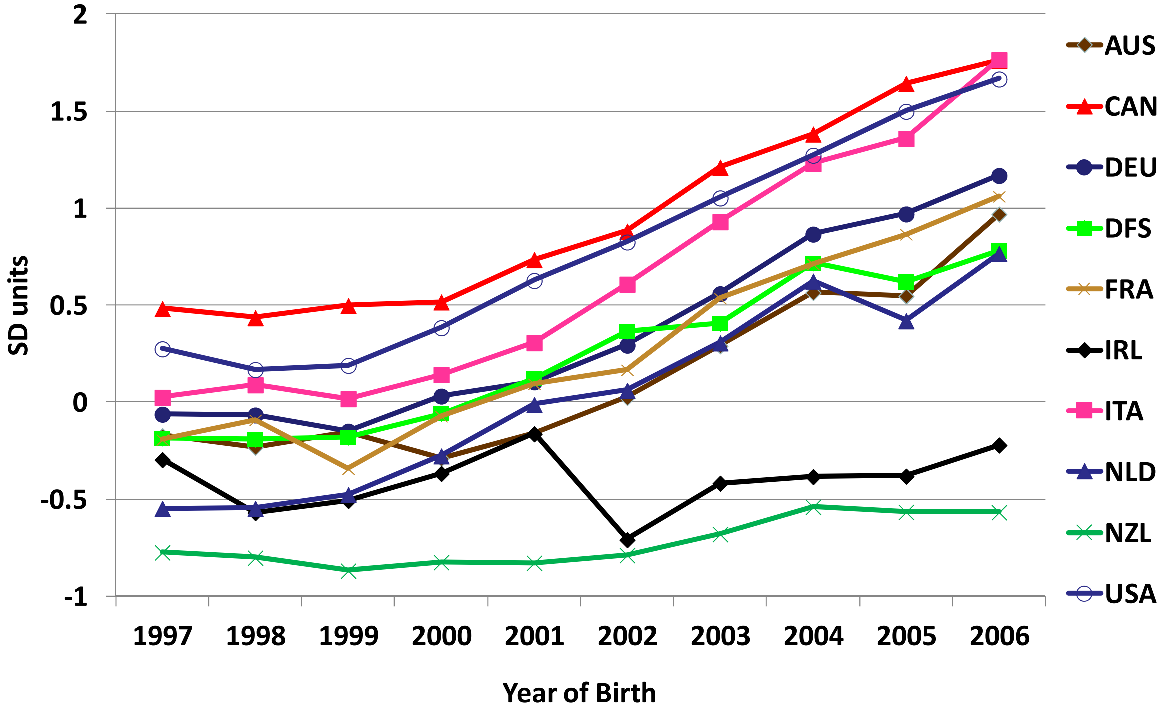


Figure 3. Bull genetic trends on the Canadian scale for longevity (expressed in SD units)

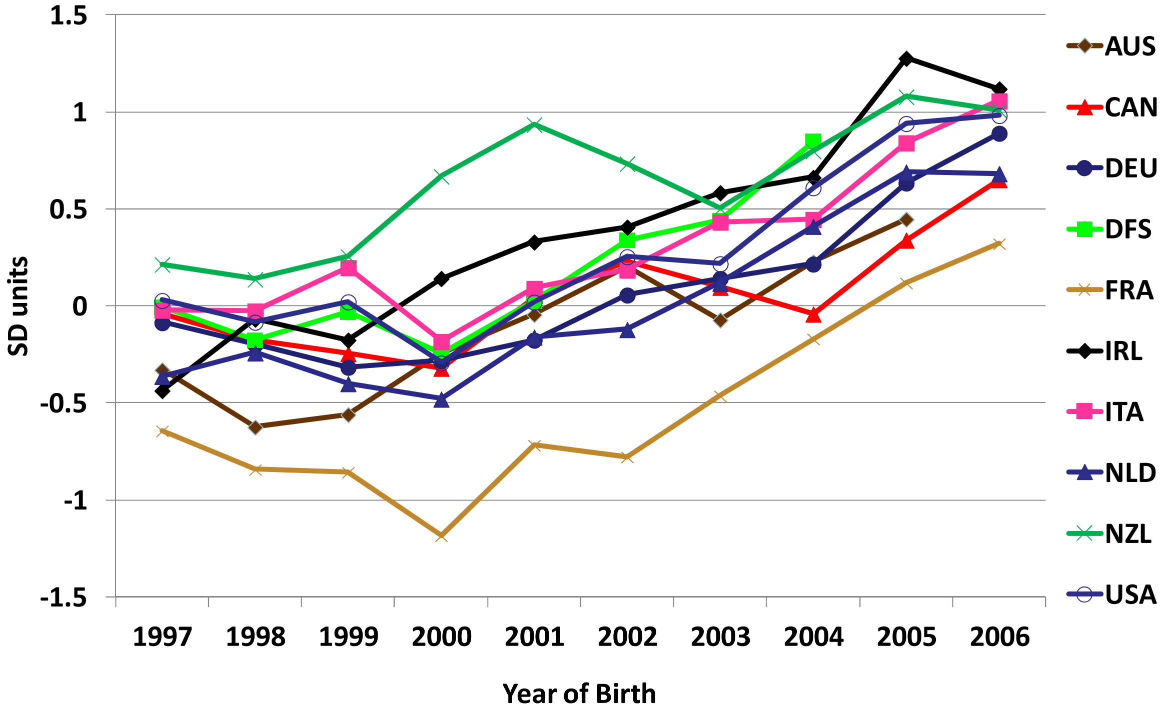


Figure 4. Bull genetic trends on the Canadian scale for SCS (expressed in SD units, lower values are desirable)

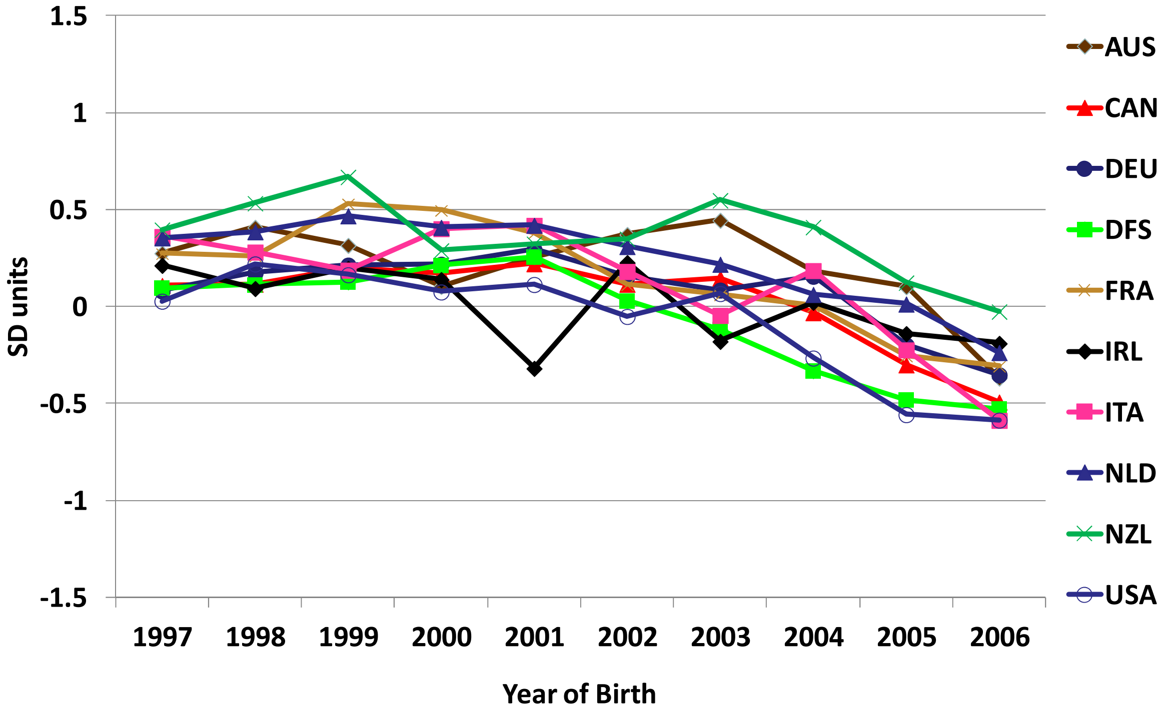


Figure 5. Bull genetic trends on the Canadian scale for Calving to First Service (expressed in SD units, higher values are desirable)

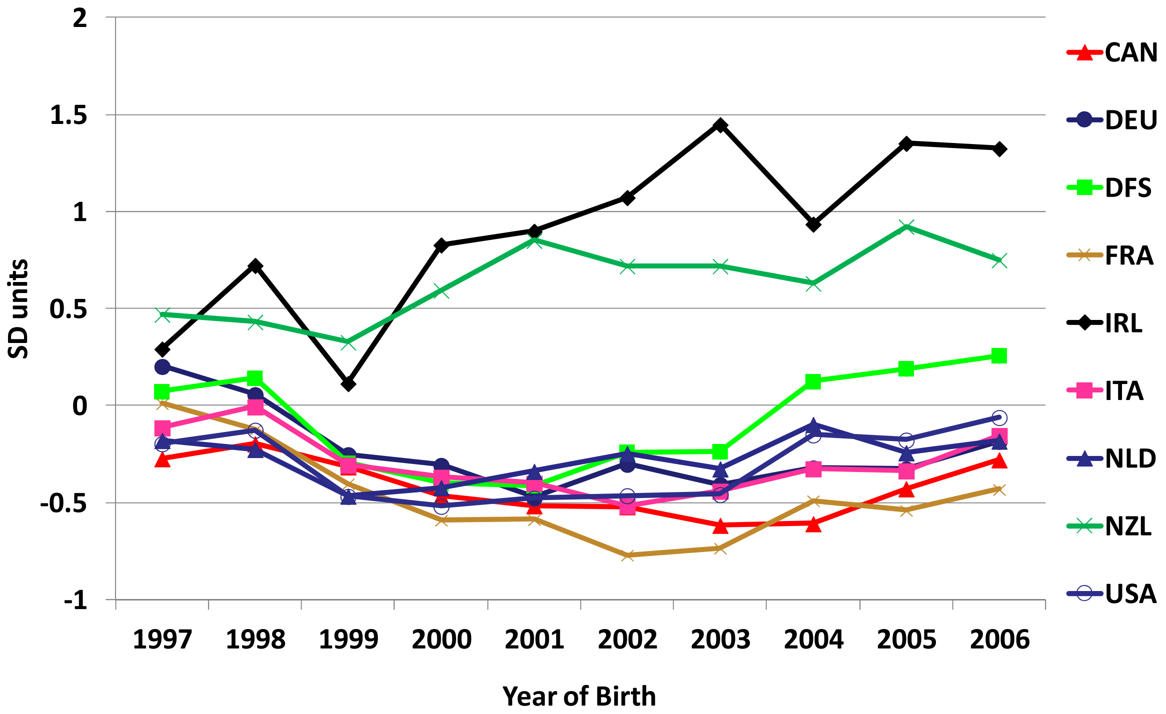


Figure 6. Average EBV of bulls born in 2005-'06 for various traits (expressed in SD units, higher values are desirable for all traits), with equal weight for every trait.

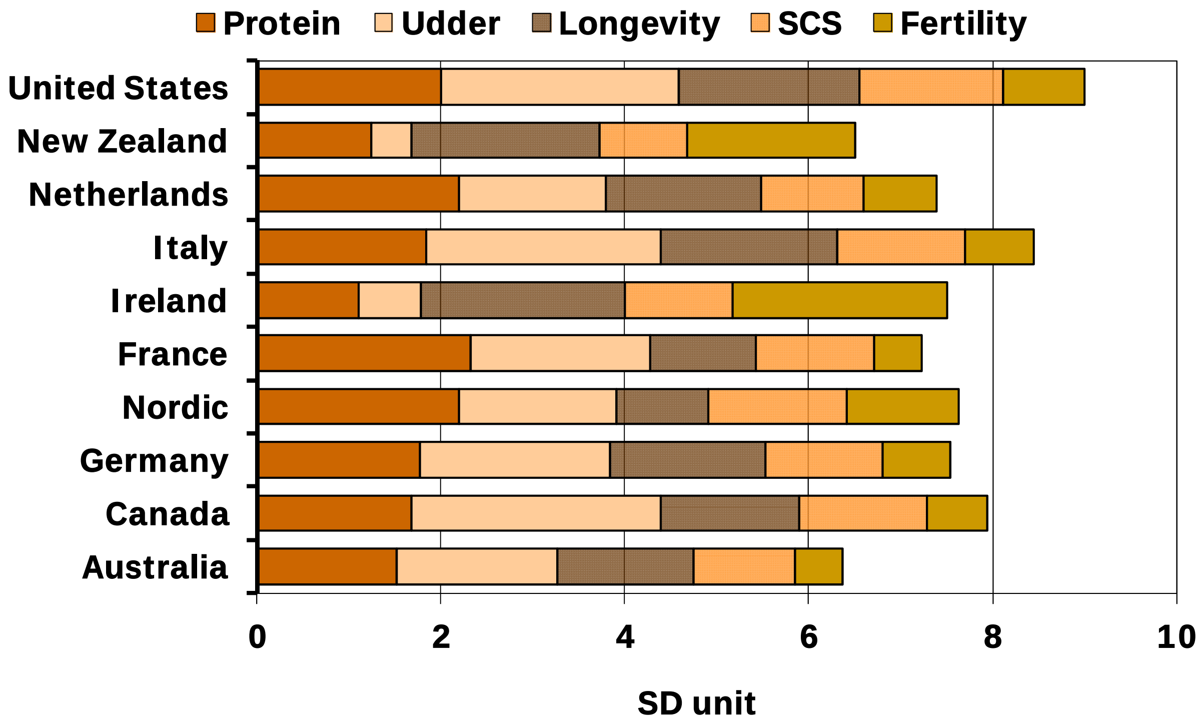
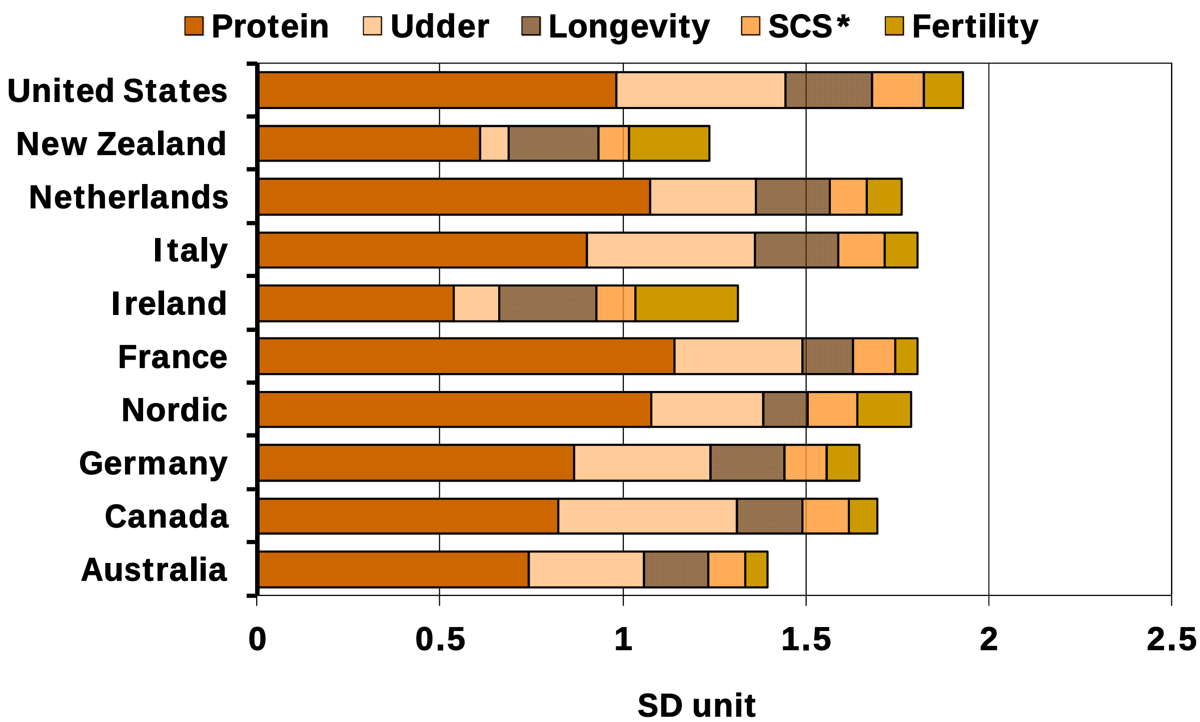


Figure 7. Average EBV of bulls born in 2005-'06 for various traits (expressed in SD units, higher values are desirable for all traits), with an average weight* for every trait (Production 49%, Type 18%, Longevity 12%, Udder Health 9%, Fertility 12%).



**Average of 18 national selection indices*

Figure 8. Yearly genetic progress by country and trait (last 5 years: bulls born in 2002-'06; expressed in SD units, higher values are desirable for all traits).

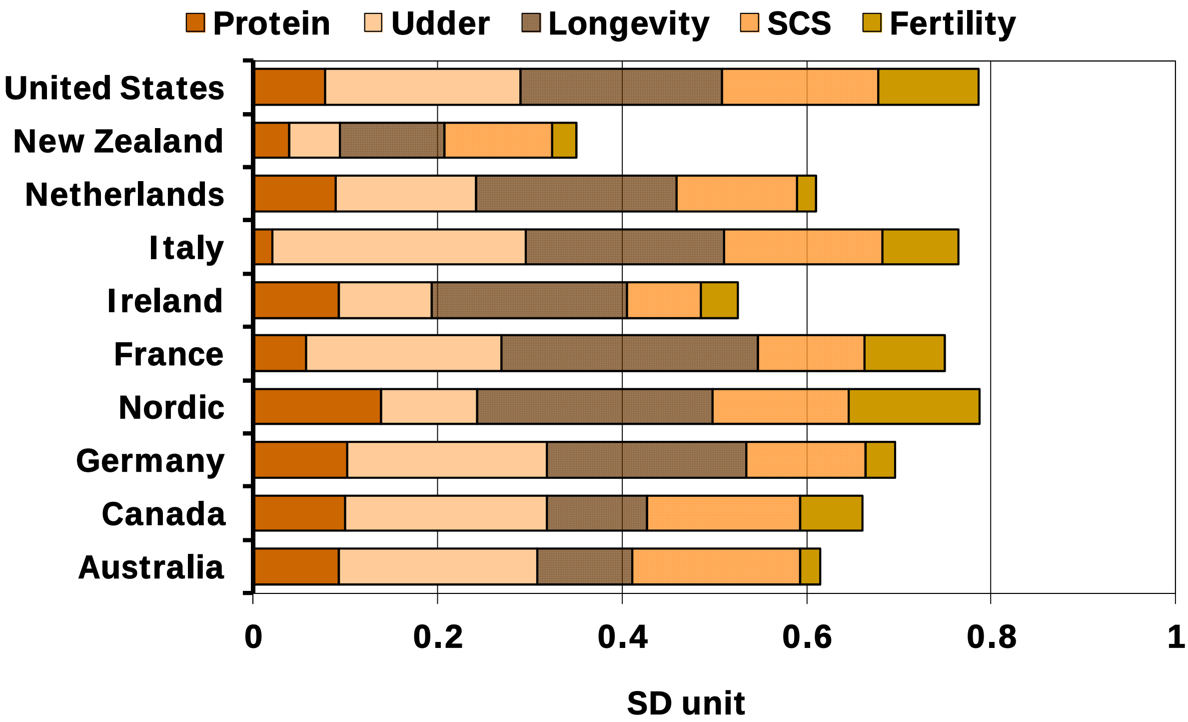


Figure 9. Cow genetic trends for some traditionally selected traits in Canada (expressed in SD units).

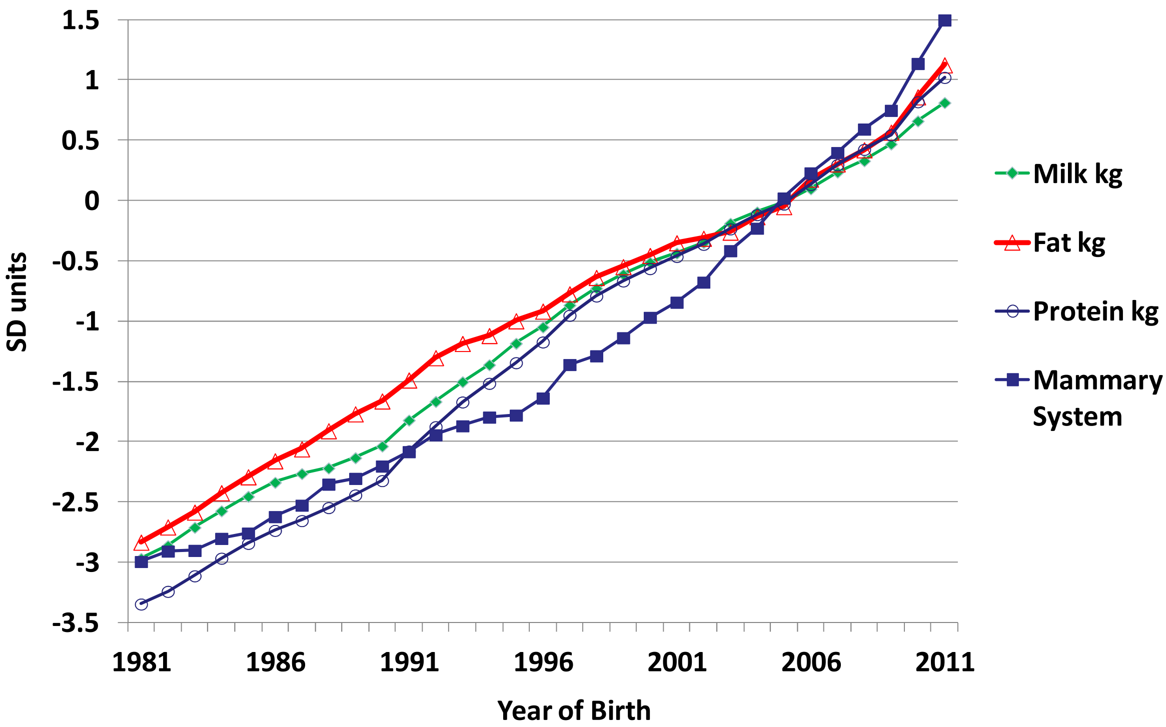


Figure 10. Cow genetic trends for SCS and Direct Herd Life (HL) in Canada (expressed in SD units).

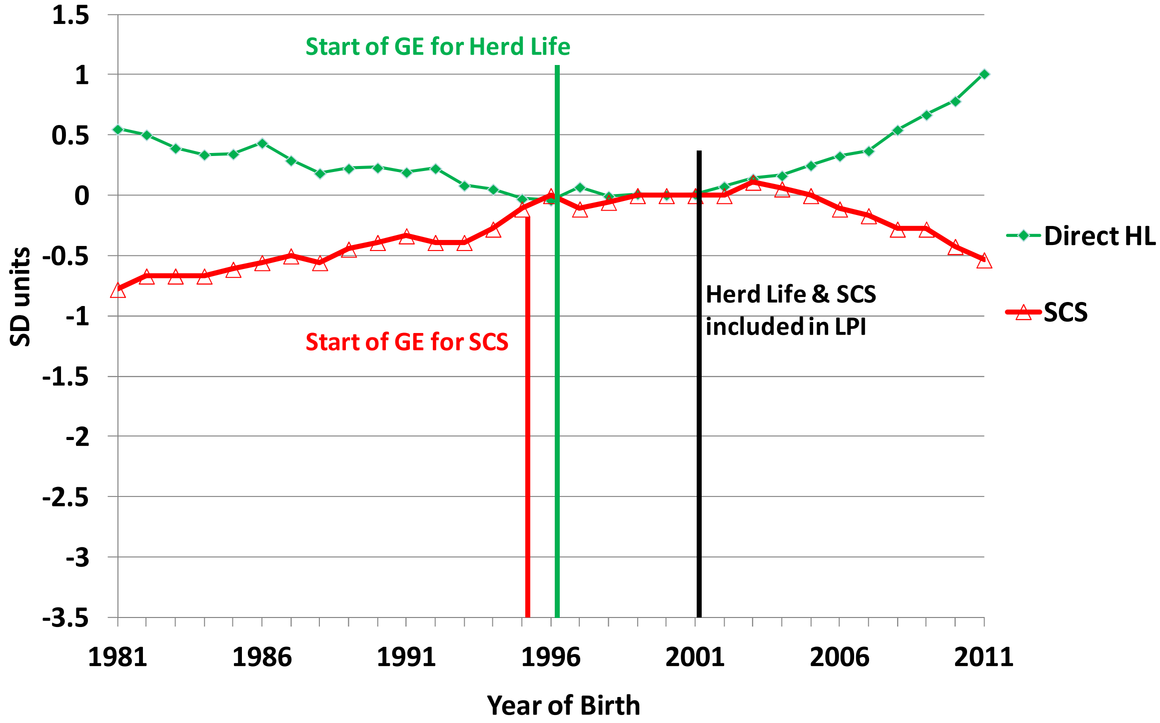


Figure 11. Cow genetic trends for two female fertility traits in Canada (expressed in SD units).

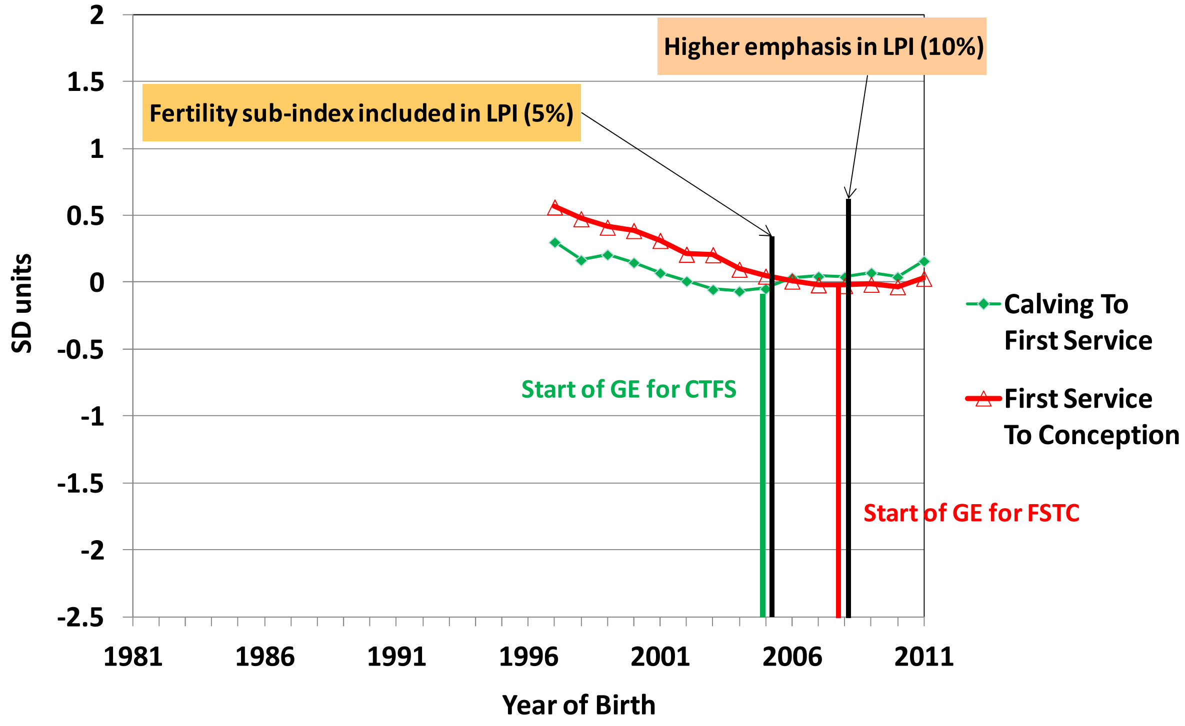


Figure 12. Yearly genetic progress by trait for Canadian cows born in 2002-'06 and 2007-'11 (expressed in SD units).

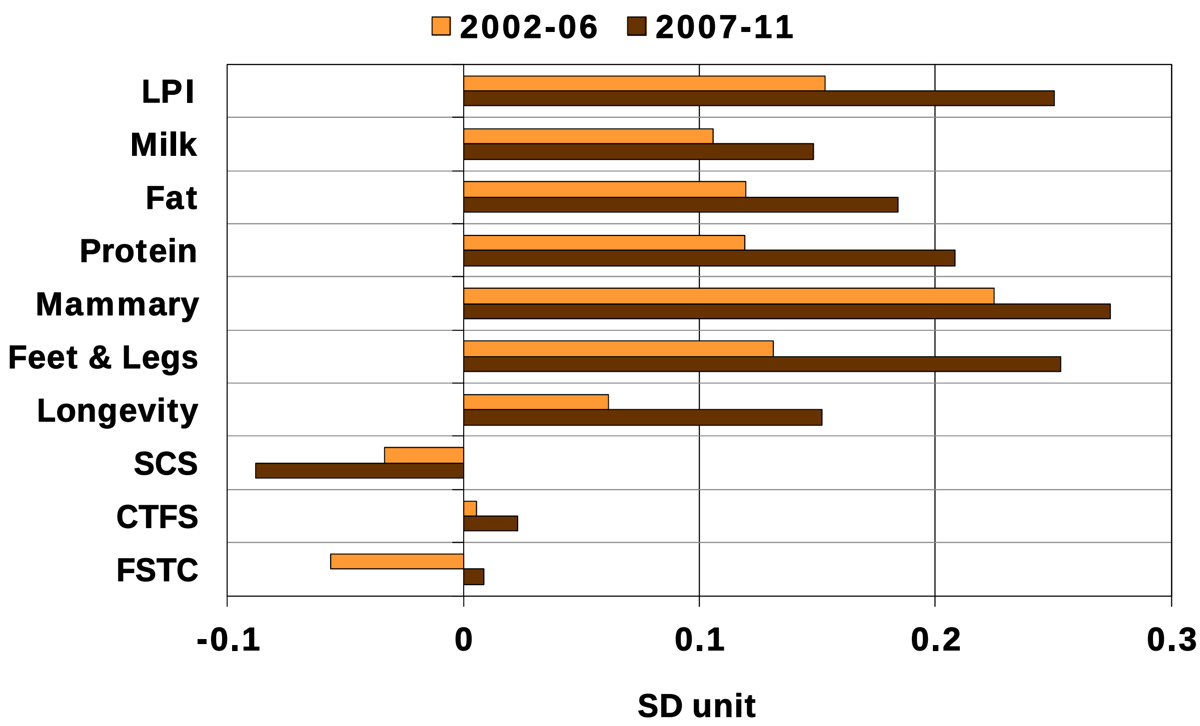
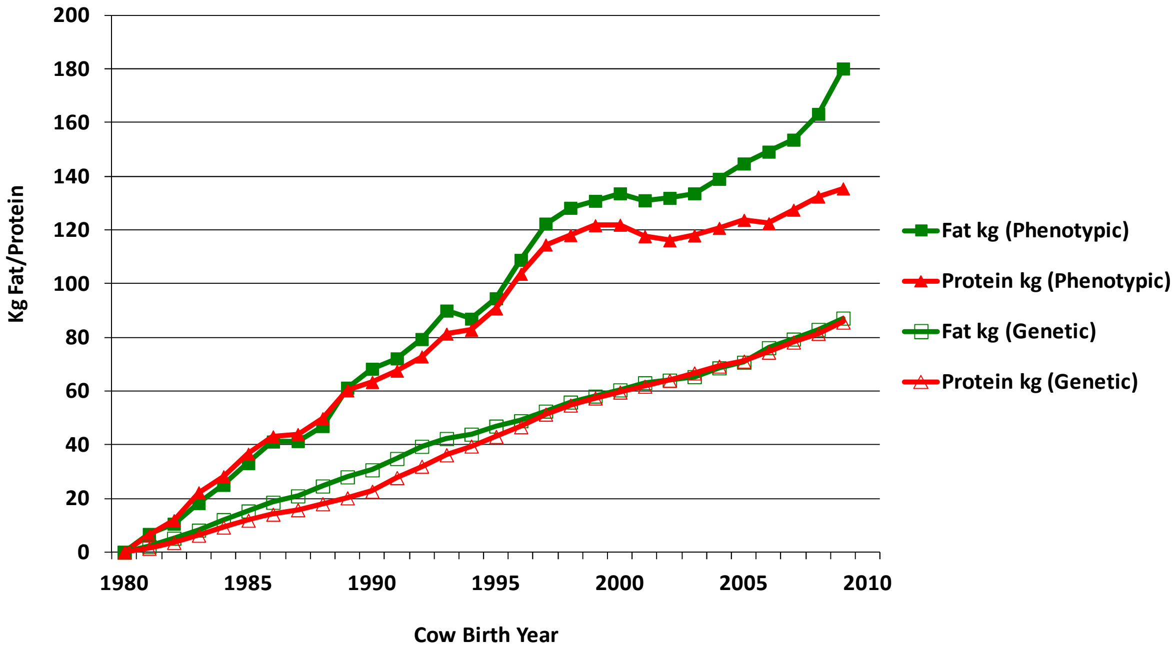


Figure 13. Genetic and phenotypic trends for fat and protein yields for Canadian Holstein cows born from 1980 to 2009.


200
180
160
140
120
100
80
60
40
20
0
Kg Fat/Protein
1980
1985
1990
1995
2000
2005
2010
Cow Birth Year
Fat kg (Phenotypic)
Protein kg (Phenotypic)
Fat kg (Genetic)
Protein kg (Genetic)