Culling/Longevity versus Genetic Progress from Heifers

Albert De Vries

Department of Animal Sciences, University of Florida, 2250 Shealy Drive, Gainesville, FL 32608
Email: devries@ufl.edu

▪ Take Home Messages

- Genetic progress in AI sires is rapidly increasing compared to just a decade ago as a result of a shorter generation interval due to genomic testing.
- Increased genetic progress through AI sires also results in increased genetic progress in heifers. Economically, this should lead to increased voluntary culling and thereby decrease cow longevity.
- It is not economically optimal to always raise all heifer calves, even with increased genetic progress.
- Optimal voluntary culling, and therefore longevity, are still more dependent on the difference between heifer raising (purchasing) cost and cow cull prices than on genetic progress.

▪ Introduction

Genetic progress occurs when animals are mated such that the offspring is expected to be superior to the population. Genetic progress in a trait from one generation to the next is the result of selection intensity, accuracy of identification of superior parent(s), and the genetic variation in the population for the trait of interest.

The available AI sires are the result of a very high selection intensity and reasonably high accuracy. AI sires are therefore vastly superior to the general population they are selected from.

Genetic lag is the difference in genetic merit between sires and dams (or more in general, between different populations). If an average cow is successfully mated with a genetically superior sire, it takes approximately 33 months before the heifer born from this mating calves for the first time and starts producing milk. Ignoring heterosis, this heifer is genetically halfway between her generically superior father and her genetically less advanced mother. When the heifer gets mated, the available sires are genetically improved compared to her already superior father. A greater genetic lag implies a larger opportunity cost of missed production because genetic merit is not as high as it could be. Of course, operational decisions such as which AI sires are chosen to mate cows, and which dams produce the replacement offspring, affect the genetic merit of the cows.

Culling affects the genetic lag in the herd. If cow cull rates are low, then longevity is high (longevity = 1 / cull rate), which means that the average cow is older and has a lower genetic merit than the average cow in a younger herd. Thus, low cow cull rates are associated with greater genetic lag. The effect of culling on average genetic merit in the herd is small, however. On the other hand, lower cow cull rates also mean lower herd replacement cost, assuming that the cost to raise a heifer is substantially higher than the cow's cull price. Further, an older herd has more mature cows which affect the herd's performance such as milk production, probability of conception, lameness, etc. Thus, there are opposing forces of replacement cost and genetic progress. The economic optimum balances both forces.

The genetic merit of heifer calves born in an older herd is expected to be lower than that of calves born in a younger herd. On the other hand, selection among heifers is possible if more heifer calves are born than are needed to replace culled cows which would increase the genetic merit of the kept heifers. Reasons for a possible surplus of dairy heifer calves are good cow comfort leading to decreased involuntary cull rates, and use of reproductive technologies leading to a higher birth rate of dairy heifer calves, for example through the use of sexed semen. Genomic testing such that the accuracy of identifying genetically superior parents is increased further complicates the question of which animals to test, breed, and cull. Therefore, the tradeoff between longevity and genetic merit in the herd is complex and not easily calculated.

The objectives of this paper are two-fold. Firstly, describe genetic trends and genetic lag in dairy cattle in the United States. Results for Canada will be similar. Secondly, review the literature on the tradeoff between longevity and genetic merit and present some additional calculations.

■ Genetic Trend and Lag

Genetic trends for various traits (milk, fat, protein, productive life, somatic cell score, daughter pregnancy rate, calving ease, and stillbirth) and for several dairy breeds in the US are available at https://www.cdcb.us/eval/summary/trend.cfm.

Looking at the trend in milk yield (Figure 1), we observe that the breeding values (BV) of milk for cows continuously lag behind those for sires. From 2000 to 2012, this lag was on average 309 kg/305 days. In the same time period, the annual increase in milk BV for sires was 60 kg/305 days and for cows it was 68 kg/305 days. Thus, cows have slightly reduced the genetic lag.

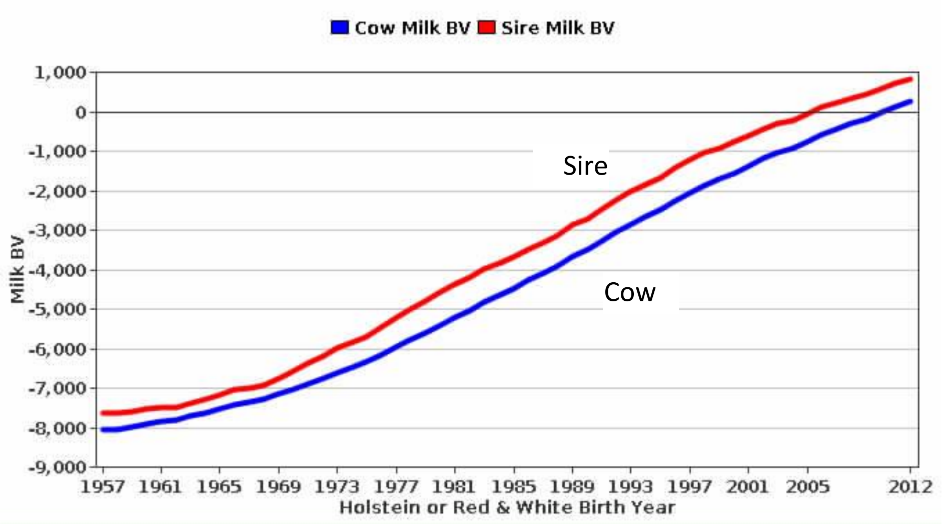

Figure 1. Trend in milk breeding values (BV) for US Holstein or Red & White, calculated December 2014 (units in pounds). The cow milk BV lags behind the sire milk BV by on average 309 kg/305 days (2000 to 2012). Source: https://www.cdcb.us/eval/summary/trend.cfm. Accessed January 5, 2015.

Productive life is defined as the time from first calving to culling. From 1960 to approximately 1985, the BV for productive life for sires was approximately 1.5 months longer than for cows. The trend was approximately 0.2 more months per year. From 1985 to approximately 2000 the trend for sires was about 0 while the cows caught up. The sire BV lagged 0.31 months behind the cow BV in 2000 but in 2011 the sire BV led again by 1.54 months, a result of an increased emphasis on selecting for productive life.

Looking at these trends for a fertility trait, daughter pregnancy rate (DPR, the percent eligible animals that got pregnant in a 21-day period), we observe sire BV that were lower than cow BV for DPR from 1957 (the first year the data are available) to 2011 (not shown). Only since 2012 is the sire BV greater than the cow BV for DPR. This is the result of increased selection for functional traits such as DPR since the 1990s. Genetic trends for other traits are not uniform but vary by trait.

USDA-AIP publishes 4 selection indices 3 times per year since December 2014: Net Merit (NM$), Cheese Merit (CM$), Fluid Merit (FM$), and the new Grazing Merit (GM$) (VanRaden and Cole, 2014). These selection indices are linear combinations of 12 traits with weights equal to their marginal economic values in 4 production systems. These selection indices are expressed as additional lifetime profit compared to the average cow born in 2010. Lifetime for Holsteins is 2.78 lactations, or approximately 3 years.

The average Net Merit$ has increased by approximately $700 from 2003 to 2014 for marketed Holstein sires (Figure 2). The annual increase is accelerating: from 2000 to 2004, the annual increase was $20 by year the sire entered AI. From 2005 to 2009, it was $52. From 2010 to 2014, the increase was $86 per year. The latest acceleration is because of rapid adoption of genomic testing since 2009, which has reduced generation interval of sires dramatically and improved the rate of genetic gain (Hutchison et al., 2014). Mean sire age for Holstein male offspring born in 2012 was 2.7 years younger than males born in 2006, and 1.43 years younger for females.

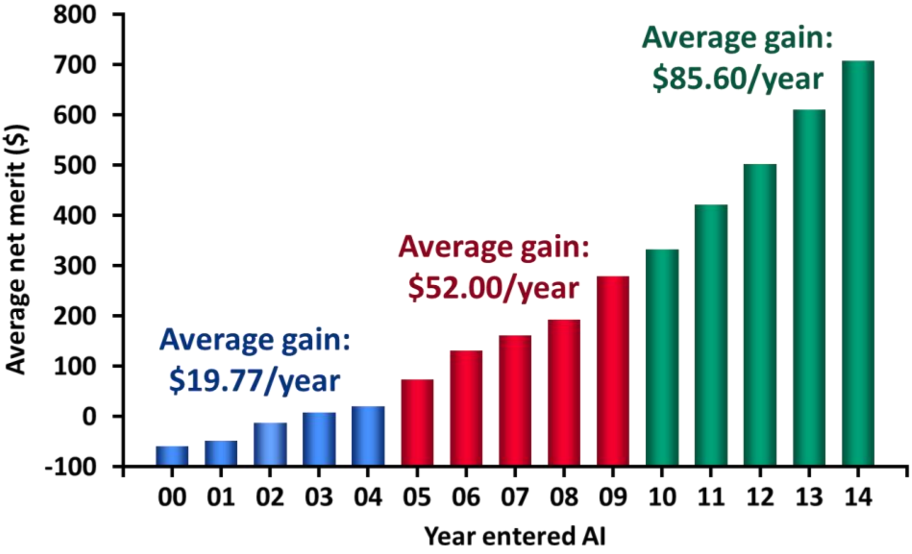

Figure 2. Average Net Merit for marketed Holstein sires by year entered AI. Source: G. Wiggans, 2014. http://aipl.arsusda.gov/publish/present.htm Accessed January 5, 2015.

Actual genetic progress is slightly lower than the theoretical genetic progress. In early 2014, actual genetic progress in EBV was about $80 Net Merit while it was $90 Net Merit in theory using the 2010 formulas for Net Merit calculation (P. VanRaden, 2014. http://aipl.arsusda.gov/publish/present.htm Accessed January 5, 2015).

The 2014 revision of the Net Merit includes new fertility traits (heifer conception rate, cow conception rate, and a redefined daughter pregnancy rate), updated genetic correlations, and updated marginal economic values. Using data from progeny-tested Holstein bulls born from 2002 through 2006, USDA-AIP expects genetic progress in EBV from NM$ (2014 revision) to be 122 kg milk/year (VanRaden and Cole, 2014). Expected genetic progress for other traits is shown in the same publication. Combined, the increase in predicted transmitting ability (PTA) for NM$ is expected to be $75/year. This means that the EBV of average animals is expected to increase by $149/year. It also means that each year heifers will on average get better by up to $149 Net Merit because the genetic trend in their mothers is expected to be similar, although with their genetic level is lower (the genetic lag).

Because Net Merit is a lifetime value (about 3 years), we can expect that heifers born in 2015 are about $50 more profitable per lactation than heifers born in 2014 ($149/3). The increase in profitability calculated from the other selection indices is similar.

Table 1. Expected annual increase in estimated breeding values from the 2014 Net Merit revision. Source: VanRaden and Cole (2014)

Trait	Annual increase	Units	Annual genetic increase in units genetic standard deviation
Protein	4.3	Kg/305 days	27%
Fat	6.5	Kg/305 days	31%
Milk	121.5	Kg/305 days	17%
Productive life	1.28	Months	31%
Somatic cell score	-0.08	Log	-21%
Udder	0.08	Composite	4%
Feet/legs	0.1	Composite	5%
Body size	-0.18	Composite	-9%
Daughter pregnancy rate	0.44	%	17%
Heifer conception rate	0.2	%	6%
Cow conception rate	0.68	%	16%
Calving ability	5.6	Dollars	16%
Net merit	149.31	Dollars	45%

Using a basic spreadsheet model to determine genetic lag in Net Merit PTA between service sires and dams in the herd, Figure 3 shows that increased cow cull rates reduce the genetic lag marginally. No selection among dams is assumed. The ratio of annual genetic trend in sires PTA for Net Merit and genetic lag is 6.6, 7.7, 8.7 and 9.4% for the annual cull rates of 20, 30, 40, and 50%, independent of the magnitude in sire genetic trend. Genetic selection among dams has little effect on genetic lag. These results confirm the findings of Allaire (1981).

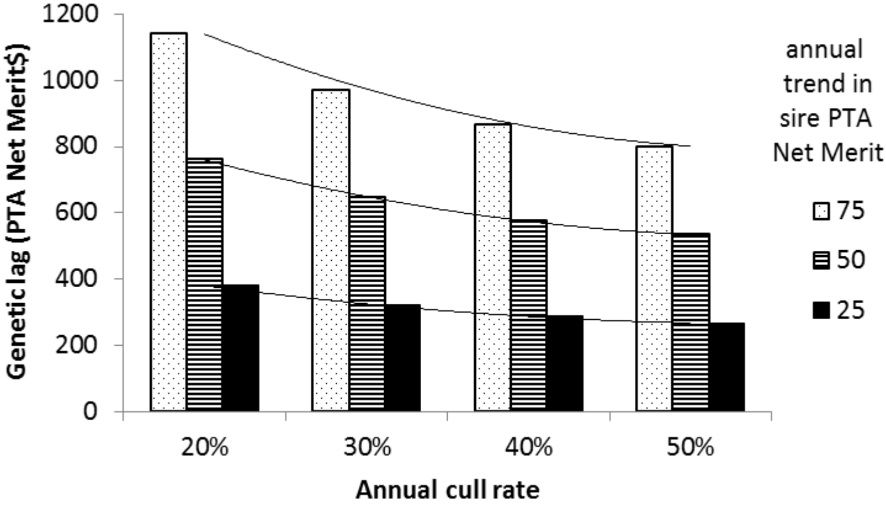

Figure 3. Genetic lag calculated as the difference in PTA for Net Merit between service sires and average dams, as a function of annual trend in sire PTA for Net Merit and annual cow cull rate. Increased cull rates decrease the genetic lag slightly while genetic trend in sires has greater effects.

■ Longevity

The average annual cull rate in US herds participating in the DHI program is 37% (DRMS, 2013). A 37% annual cull rate is equivalent to a phenotypic productive life (time between first calving and culling) of 32.4 months. Table 2 shows associations between the annual cow cull rate and various herd statistics from cows on DHI test. The highest cull rates are associated with reductions in herd size, more calvings per cow per year, and more heifers per cow. Associations with reproduction and milk production are less clear, with the more desirable statistics found for medium cull rates.

Table 2. Association between annual cow cull rates and herd statistics for 13,357 U.S. dairy herds participating in DHI milk test

	Annual cow cull rate (%)						
Herd statistic	13-20%	21-27%	28-34%	35-41%	42-49%	49-55%	56-62%
Herds (N)	531	1645	3169	3422	2193	933	416
Cows left per year (%)	17	25	31	38	45	51	59
Cows (N)	109	109	157	198	192	153	153
Change in herd size (%)	13.7	7.2	4.1	1.8	-0.5	-2.5	-5.4
Rolling milk yield (kg/yr)	7834	8661	9356	9781	9811	9588	9399
Calvings/cow present (%)	91	96	101	106	111	113	118
Heifers/cow (%)	76	82	86	92	97	101	102
Calving interval (mo)	14.3	14.1	14.0	13.8	13.8	13.9	13.7
Conception rate, 1st (%)	47	47	44	43	43	44	46
Heats observed (%)	41	42	44	46	46	43	41

Source: DRMS (2013). Available at www.drms.org Accessed May 9, 2013

▪ Tradeoffs between Longevity and Genetic Progress

To recapture, the basic question is how should genetic progress in replacement heifers affect cow culling and therefore longevity.

Replacing cows with genetically superior heifers is an application of the general problem of asset replacement with technologically improved assets. Groenendaal et al. (2004) summarized the standard economic theory, showing that cows should be replaced sooner when the incoming heifers are genetically improved. The theory says that “the optimum time for replacement of a dairy cow is determined by comparison of the marginal net revenue anticipated from the present cow with the economic opportunity of a replacement. The latter value equals the maximal average discounted net revenue anticipated from replacement cows, also reported as annuities. For a situation with identical replacement or genetically improved replacement, the optimum time of replacement is defined as the first time period in which the annuity value of the cow drops below the maximal annuity value of the replacement animal." This is a little bit easier said than realistically calculated.

Several studies have tried to address the tradeoff question of culling vs. genetic progress. A complete analysis considering all effects is complicated because there are interacting effects of (at least): 1) involuntary cow culling, 2) voluntary cow culling, 3) choice of dams to supply the next generation of replacement heifers, 4) number of heifers required to replace culled cows, and 5) genetic progress from sires.

An elegant, rather complete but now old study is from Allaire (1981). He included all 5 factors from the previous paragraph to determine optimal cull rates, as well as increase in milk sold per cow and increase in profitability after 20 years of culling and selection. The model included culling and selection based on milk yield only. In the model, he assumed that youngstock culling was proportional to cow culling, so when cow culling increased, so did youngstock culling. He found that optimal cull rates were 30 to 35% when the objective was maximum milk sold per cow. The gain from keeping heifers from random survivor dams after voluntary culling was slightly smaller than the effect of voluntary culling only for low milk yield around the 35% cull rate. This effect of culling was equivalent to at least 25 years of genetic gain from dam selection. When the calves from the best dams among the survivor dams were used to generate the next generation of heifers, the additional gain was quite small because at 35% cull rate, few surplus dams were available; thus, selection intensity in dams was low at higher cull rates. No genetic progress from sires was considered in these cases. Considering a 0.5% annual increase in milk yield from sires, the gain was equivalent to the gain from breeding the best surviving dams and voluntary culling. These optimums around 35% cull rates to maximize milk yield do not include the cost of raising heifers and the price of cull cows. These herd replacement costs are obviously greater at 35% cull rates then at lower cull rates.

When Allaire (1981) included herd replacement costs that were relevant in Ohio in 1979, the result was that the economically optimal female cull rates were in the range of 20% to 23%, only 0 to 3 percentage points above the 20% involuntary cull rate he assumed. Expressed per cow, the economic optimal cull rates were in the range of 25% to 27%, compared to an involuntary cull rate of 20%. There was only a small effect of using the best surviving dams compared to random surviving dams to generate the replacement heifer calves. Allaire's (1981) findings that a much reduced cull rate would maximize profitability, at the cost of genetic progress, were previously proposed by Hill (1980). Significant cow depreciation (the difference between heifer raising cost and cow cull cost) reduced optimal cull rates and hence genetic progress from both selection and culling among dams, and genetic progress among sires was reduced. Although the Allaire method used is elegant, the results are somewhat outdated because of assumptions in prices, milk yield, and annual genetic progress in sires. It is, however, not a trivial task to repeat his analysis.

Van Arendonk (1985) studied optimal replacement policies in dairy cattle, including the effects of genetic progress on milk yield from using superior sires over time. These optimal culling policies were much more detailed than those assumed by Allaire (1980) and were economically optimal, but genetic progress from the dam side, either through voluntary culling or generating offspring from the genetically better dams, was not considered. Annual sire genetic improvement was set at \$5.45, \$10.91, or \$16.36 (1985 values, roughly \$12, \$24, or \$36 in 2014 dollars). Optimal annual culling rates changed only from 27% to 30%. The proportion of cows for which replacement was voluntary, instead of involuntary, increased from 23% to 32%. He concluded that the effect of changes in genetic improvement in milk revenue minus feed cost on average herd longevity was relatively small. Reduced involuntary cull rates improved profitability, but also simultaneously increased optimal voluntary culling. Therefore, he further concluded, from an economic point of view, management and breeding policies should be directed toward reduction of involuntary disposal rather than maximization of the average herd life of cows.

The findings of Allaire (1981) and Van Arendonk (1985) are further confirmed with the following analysis. Increased genetic merit in calving heifers is expected to be expressed during their lifetime. A better heifer with an EBV of +\$100 is expected to generate approximately \$33 more per year than an average heifer with an EBV of \$0. Considering discounting for future income into today's net present value, and considering that the better heifer's offspring are also expected to be somewhat better than average, we might use a factor of 1.4 to put the EBV of \$100 NM\$ into today's net present value of +\$140. Subtracting the \$140 value from the raising or purchase cost of the average heifer means that the herd entry cost of the +\$100 NM\$ heifer are \$140 lower than the herd entry cost of the average heifer. If the average heifer costs \$2000, then we might consider the better heifer to cost only \$1860. So should heifer cost of \$1860 vs. \$2000 significantly change the cow cull rate?

Using updated inputs for a typical U.S. dairy herd in 2014 and a model (De Vries, 2006) similar to the one used by Van Arendonk (1985) that optimized culling decisions, we varied heifer entry prices and observed cull rates as well as the surplus of dairy heifer calves generated. Surplus dairy heifer calves occur if the number of calves available for replacement is greater than the number needed to replace culled cows. Some key results are in Table 3 for two levels of estrus detection rate leading to pregnancy rates of approximately 25% and 20%. The data show again that annual cull rates are somewhat insensitive to heifer prices and therefore insensitive to superior genetics in heifers. With lower heifer prices, profitability increased, annual cull rate increased, and the rate of surplus heifer calves decreased. A negative surplus implies that the herd has a shortage of heifer calves and additional heifers need to be purchased. In the case of the lower pregnancy rate (20%), surplus = 0 when the heifer price was $1590. Using the culling policy associated with the $1590 heifer price, the profit/cow/year was $518 when the heifer price was $2000, or $66 lower than when the culling policy was optimal for the $2000 heifer price.

The results show, in agreement with the older results of Allaire (1981) and Van Arendonk (1981), that genetic progress in sires is not fast enough to warrant a high cull rate (resulting in a short longevity) and bring all heifer calves into the herd. The cost of cow depreciation is a bigger factor deciding optimal cull rates. However, genetic progress does reduce the economical optimal longevity somewhat.

Table 3. Optimal annual cull rate and surplus of dairy heifer calves as a function of heifer price calculated with a model with economically optimal culling decisions

Heifer price, $	Profit ($/cow /year)	Pregnancy rate (%)	Annual cull rate (%)	Surplus heifer calves (%)
1400	818	25%	59%	-22%
1600	720	25%	41%	8%
1800	647	25%	34%	21%
2000	584	24%	30%	28%
2200	526	24%	28%	32%
1400	801	21%	64%	-30%
1600	696	20%	44%	2%
1800	617	20%	36%	15%
2000	550	20%	32%	22%
2200	488	20%	30%	26%

■ Summary and Conclusions

Genetic progress in AI sires is rapidly increasing compared to just a decade ago as a result of genomic testing and a shorter generation interval. This means that increased genetic progress through AI sires also results in increased genetic progress in heifers. Following asset replacement theory, and confirmed by calculations by dairy scientists, this means that cows should be replaced a little faster, thereby decreasing the time cows spend in the herd. Even with increased genetic progress in sires, it is not necessarily economically optimal to raise all heifer calves. Alternatives may be to sell some heifers, or use some beef semen. Optimal voluntary culling, and therefore cow longevity, given some level of involuntary culling, is still more dependent on the difference between heifer raising cost and cow cull prices than on genetic progress. This is confirmed by old and new studies. The best decision depends on many prices as well as somewhat on the rate of genetic progress. Genetics is not the leading factor when it comes to cow longevity.

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