Genomics: Return on Investment - Fact or Fiction?

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Introduction

For nearly a decade, genomic technology has been incorporated into selection decisions made in the livestock industry. Genomic technology can be used in livestock production (cattle) in several ways: 1) accelerating genetic progress by increasing selection pressure through the use of genomically-tested seedstock, 2) selecting for difficult to measure traits (feed intake, etc.) 3) selecting replacement heifers at both the commercial and seedstock level, 4) marketing and selling pedigreed livestock at premium prices, 5) determining parentage in multiple sire pastures and for sire/dam verification for increased accuracy in genetic predictions, 6) monitoring genetic mutations to avoid economic losses from affected progeny, 7) developing and deploying mating plans to achieve genetic gain while controlling inbreeding and 8) combining genomics, EPDs and reproduction technologies (IVF-MOET, Embryo Transfer, single cell analysis on embryos) to rapidly accelerate genetic change and reduce generation interval. The rate of adoption of genomic technology has varied between livestock species, as well as between breeds and segments within the species. Initially, adoption was primarily hindered due to cost, efficacy of the tests and scope of the traits available for genomic selection.

Today, for most species and many breeds within those species, moderately efficacious tests are utilized across a wide variety of traits, however the debate still exists on how to determine when the technology is economically beneficial for the end-user producer. This paper will discuss the application of genomic technology and potential return on investment (ROI) for the various phases of the U.S. beef cattle industry: seedstock, commercial/cow-calf, and feed yard. While many of the published ROI examples are from dairy, it is expected that similar thoughts can be applied to beef and several research groups are working toward that end.

How does genomic analysis pay?

The potential streams for return on investment for genomic technology can be sorted into two categories, increases in profit due to genetic improvement and increases in profit unrelated to genetic improvement.

In order to recognize a return on investment due to genetic improvement, more rapid genetic progress must be made through manipulating the variables impacting the rate of genetic change (accuracy of selection, selection intensity, generation interval, and genetic variation (Figure 1)) and/or realizing cost savings due to decreased expenses associated with retaining breeding animals or gains in efficiency due to performance. Items unrelated to genetic improvement, but that may provide a return for investing in genetic technology are making better mating decisions and marketing animals.

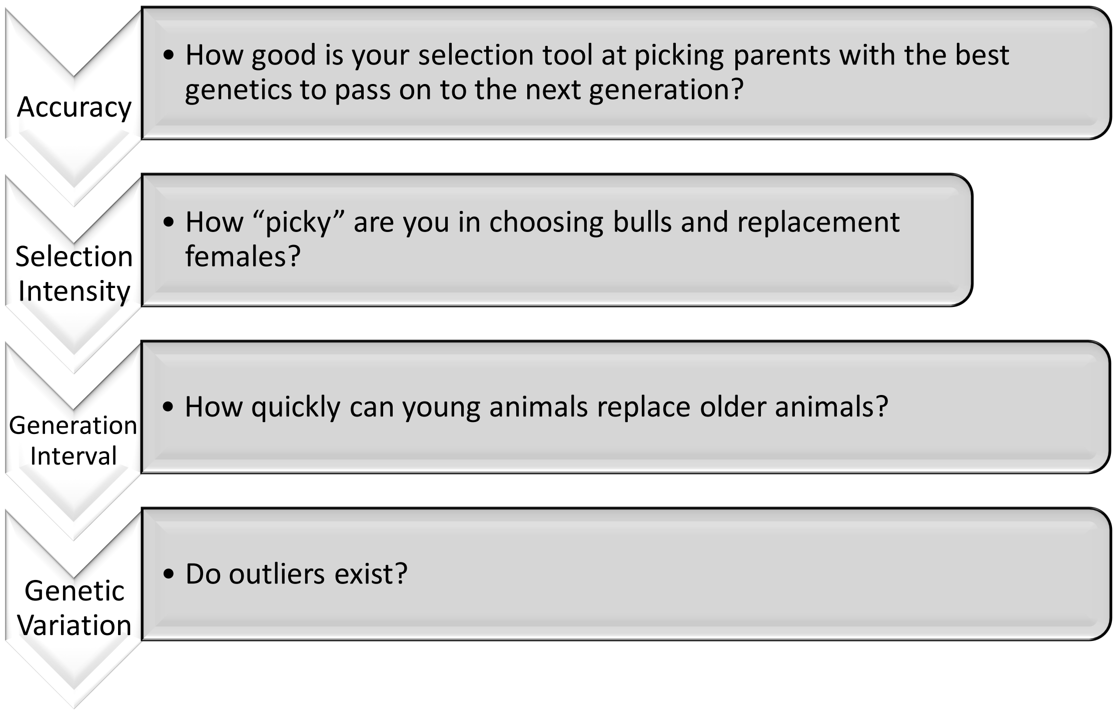


Figure 1: Variables Impacting Rate of Genetic Change

Seedstock

Early on, the return on investment for genomic testing was recognized in the dairy industry.

In their model of the German dairy industry, König et al. (2009) showed the economic advantage in various genomic breeding programs compared to the conventional progeny-test breeding program that was typical at the time. Genomic breeding programs considered costs of genotyping, selection intensity, degree of use of young sires with genotypes only compared to young bulls with some daughter records, and different accuracies for genomic indexes for bulls and cows. In all scenarios considered, genomic breeding programs offered 1.36 to 2.59 times the economic advantage over a traditional program. This assumed that the accuracy of genomic EBVs was at least .7, which would be equivalent to about .29 for BIF accuracy. This is less than the accuracy attained by genomic-enhanced EPDs currently offered by most beef breed associations.

Similarly, in a small, Dutch dairy population, Thomasen et al., (2014) showed that all genomic selection scenarios (one a hybrid system using both progeny-tested bulls and young genomically-tested bulls and the other a system using only young, genomically-tested bulls) were superior to the conventional progeny-test system from a profit standpoint.

In beef cattle in Australia, Van Eenennaam et al. (2011) estimated that use of genomic testing increased selection response between 29 and 158% depending on marketing method and the type of index (maternal or terminal). For commercial bulls and stud bulls, this improvement was valued between AU$89-$565/hd and $5,332-$27,910/hd, respectively, above traditional performance testing. On a per test basis (because the entire bull calf crop was tested, but not all went on to be AI sires or even commercial bulls) the value of the DNA test was $204-$1,119 per test purchased.

Increasing revenue due to an improvement in the rate of genetic change caused by improved accuracy of selection criteria is certainly partially responsible for economic advantages obtained through genomic testing. However, some studies in dairy cattle have suggested the majority of the economic advantage is derived from cost savings associated with keeping, testing, and maintaining fewer bulls for shorter periods of time (Thomasen et al., 2014, Pryce and Hayes, 2012).

This cost savings was illustrated nicely in New Zealand, where prior to implementation of genomic selection, one farming cooperative progeny tested nearly 300 bulls per year. After adopting the use of genomic testing in young bulls, the number dropped to 160. It was estimated that at that time, the cost to progeny test a bull was $NZ30,000-$40,000 (Spellman, 2012). Thus, progeny testing fewer bulls resulted in a savings of $4.2 million. Additionally, the increased use of young sires was estimated to increase genetic gain by 40-50%.

Similarly, Schaeffer (2006) estimated progeny testing bulls would cost the Canadian AI industry CAD$25 million/year (500 bulls at $50,000 per bull). If this cost were attributed only to the 20 bulls returned to service, the cost of progeny testing was $1.25 million/bull at that time. After accounting for generation interval, accuracy of selection, and selection intensity the cost to the industry of changing the population by one genetic standard deviation was $116 million. The cost for implementing a genomic selection scenario was estimated to be $1.95 million in total, but that investment reduced the cost of proving bulls by 92% and the cost of a one genetic standard deviation change was reduced to $4.17 million. This a is reduction in cost to the industry of over $111 million/yr at a time when the cost of genotyping was $500/hd.

Commercial/Cow-calf sector

Work in the dairy industry has shown that the major factors impacting return on genomic selection at the commercial level are: the cost of the test, the accuracy of the test, the proportion of females that will be retained, and the information already available to make selection decisions (Spellman et al., 2012; Pryce and Hayes, 2012; Weigel et al., 2012), preliminary work in the U.S. cow/calf sector indicates the factors impacting return on investment for testing would be similar.

Weigel et al. (2012) examined breeding strategies that used genomic testing in commercial dairy females compared to breeding strategies that did not. After accounting for the cost of testing in the selected females and their unselected contemporaries, they analyzed the difference in the lifetime net merit breeding value (LNM$). In all cases, the strategies that used genetic testing resulted in higher LNM$. However, the greatest advantages where seen when testing was done in the youngest animals (heifer calves) with very little other information (no known pedigree) and when selection intensity was very high (many animals were culled). For example, LNM$ averaged $28 more for selected females than their unselected contemporaries when the top 90% were retained, when only the top 20% of females were retained, the difference grew to $259. When sire was known, the differences between keeping the top 90% vs the top 20% shrunk to $14 and $121, respectively.

Decker (2015) used the University of Missouri herd as an example for the value of genomic testing in commercial beef cattle. These high-percentage Angus commercial heifers were tested with GeneMax™ Advantage test from Zoetis. The average Total Advantage score for all tested heifers was 77.8 (Figure 2). If the top 60% of the heifers were kept, (the bottom 40% culled) the average increased to 86.2 (Figure 3), at $1.50/per 1-point increase in score, this meant that the selected heifers were expected to be $63/hd more profitable over their lifetime (assuming 5 calves) than the whole group (Figure 4).

Figure 2. Average, minimum and maximum GeneMax Total Advantage scores for all tested heifers.

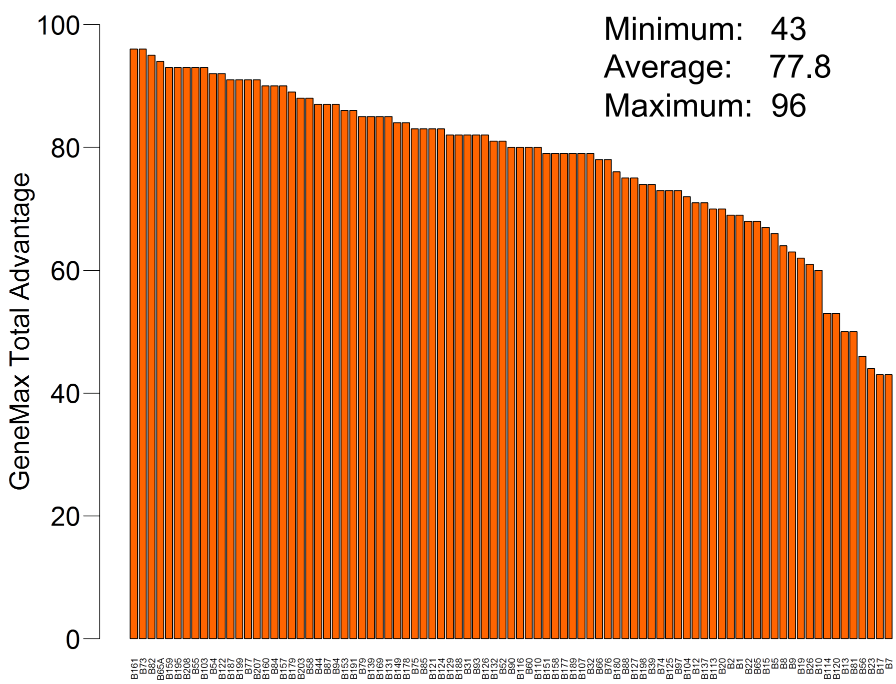


Figure 3. Average, minimum and maximum GeneMax Total Advantage scores for top 60% of heifers

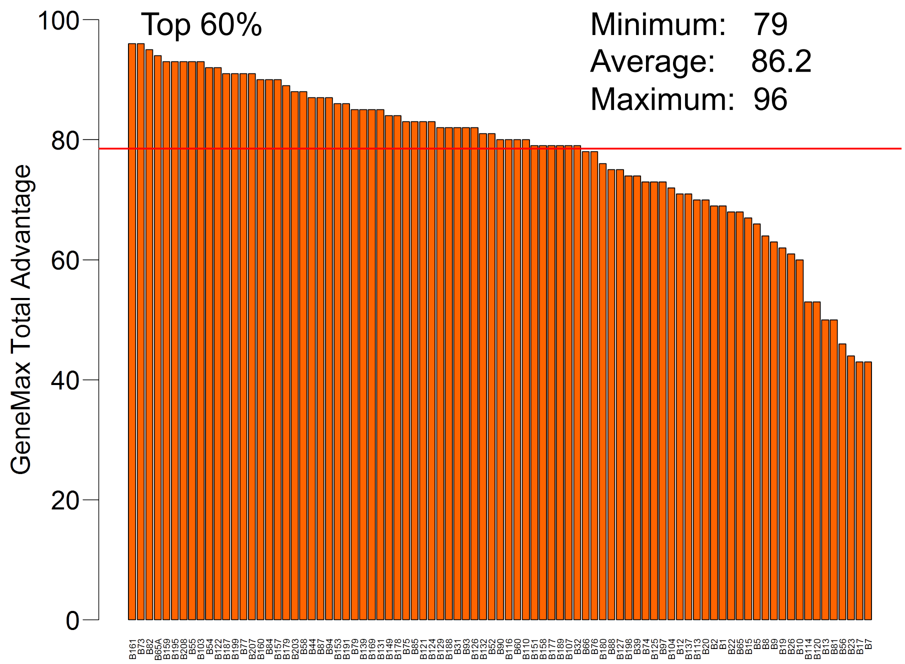
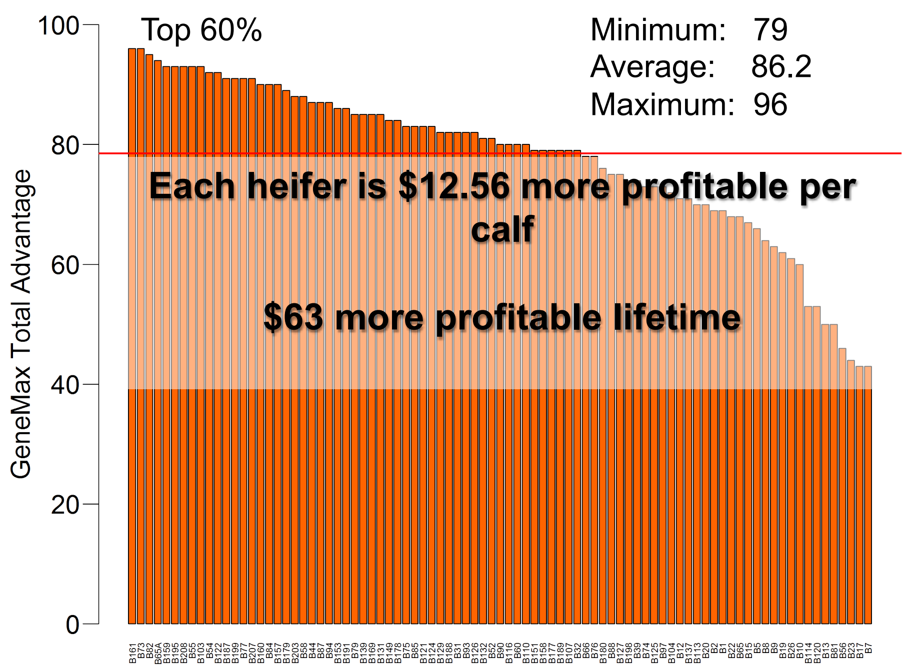


Figure 4. Annual and lifetime profit difference between the tested group and top 60%.



Several published documents do caution that genomic testing at the commercial level may not pay in all instances. Van Eenennaam and Drake (2012) estimated that in Australia, the breakeven cost for DNA testing all potential replacement candidates (when no other information was available) was AU$13 for the domestic market and $24 if targeting the export market. If other sources of information were available, such as the heifer's own 400 day weight, this breakeven cost dropped to $8. It's important to note that this analysis only evaluated the benefit of the technology for retaining animals in the herd, but using the technology to make mating decisions was not considered, which is a loss in the value of the technology.

Pryce (2014) also explored the economic returns expected when genomic-tested females were retained as replacement heifers in the Australian dairy industry. In a 100 cow dairy, when the cost of the genomic analysis was $AU 60 and the majority of heifers were needed as replacements, there were situations when testing did not make economic sense (Table 1). However, when the cost of the test was lowered to $40, all levels of selection intensity favored use of genomic technology (Table 2). Again, this analysis focused on the value of genomics for selection purposes, but not the value of using results for more strategic mating.

Table 1. Net Profit after Genotyping Costs at $60/hd

		Heifers retained			
		15	20	25	30
Heifers available	20	-5.07			
	25	13.87	-13.11		
	30	21.10	6.45	-18.98	
	40	18.82	21.10	1129	-5.07
	50	4.96	20.81	21.10	13.87

Table 2. Net Profit after Genotyping Costs at $40/hd

		Heifers retained			
		15	20	25	30
Heifers available	20	21.60			
	25	47.20	11.89		
	30	61.10	36.45	5.02	
	40	72.16	61.10	43.29	21.60
	50	71.62	70.81	61.10	47.20

Feeder Cattle

Early promise for genomic technology suggested that perhaps it could be used to manage feedlot cattle by sorting them into similar groups based on genomic results. However, Thompson et al. (2014) showed that increases in profit due to marker assisted management were extremely small (less than $3 per head). On the other hand, using genomic results to select cattle for placement in the feed yard holds more promise with expected increases in profit by up to $38/hd, with average daily gain and marbling being the traits that contribute to the greatest increase in profit. In fact, there are programs that have been deployed in the industry in the last 3 years that have recognized the benefit of genetically differentiating feeder cattle (for example Top Dollar Angus and Reputation Feeder Cattle).

Compared to traditional methods of marketing feeder cattle (marketing whole groups live, dressed, or on a grid), using genomic technology to sort them into marketing groups does improve the opportunity for profit (Thompson et al., 2015). However, profit realized (from $1-$8.51/hd depending on how cattle were marketed previously compared to after using genomic results) is not enough to cover the cost of genomic testing at this time.

So, for use in feeder and fed cattle, it appears that genomic technology holds the most promise for use in selecting them for placement (Thompson et al., 2014; Thompson et al. 2015). With commercially-available tests, targeted panels that focus on the key profit-driving traits (currently, marbling and gain) are the most promising for a return on investment. However, if there was a value proposition for palatability traits such as tenderness, genomics would be a key driver in realizing a more consistently palatable product to the consumer and more profit to the producer (Weaber and Lusk, 2010).

In the meantime, an opportunity exists to test a random sample of animals and extrapolate results to make informed decisions, and achieve significant return on investment (up to 250%) while testing as few as 10% of the animals (Thompson et al., 2016) in a management group.

With continued research, the potential exists to use genomics in feedlot cattle to manage cattle for performance, health status, and response to certain treatment regimes. Also the possibility to use genomics to understand the interaction of microbiome DNA with host DNA to improve economic traits such as feed efficiency (Roehe et al., 2016).

Avoiding Inbreeding

Hybrid vigor and inbreeding depression are the two measureable factors related to the way that genes combine due to mating decisions that cannot be over-looked both from the standpoint of animal performance as well as the opportunity for genomics to contribute real returns.

Inbreeding is defined as the mating of individuals that share a common ancestor and it has implications because it's been shown to have a deleterious impact on fertility, longevity, disease resistance and other lowly-heritable traits. In addition, inbreeding can increase the risk recessive abnormalities. The ability of genomics to more accurately measure and manage inbreeding is an under-utilized feature of the technology that should yield returns in improved performance and greater return on investment for genomic testing.

Pryce (2014) indicated that a 1% increase in inbreeding decreased milk production by 21 liters, and decreased fat and protein by 0.73 kg and 0.63 kg, respectively. For every 1% increase in inbreeding, these performance reductions were estimated to cost $20 per cow.

Classically, avoiding inbreeding has been managed through pedigree relationships and assuming that relatives shared a certain quantity of their genome due to inheritance from a common ancestor. In fact, relatives may have much more in common than a simple pedigree relationship would reveal. To do a better job of managing inbreeding Pryce (2014) illustrated that using current high-density and low-density genomic panels could be used to do a better job of managing inbreeding by calculating genomic relationship between animals. Using mating software combined with a threshold level of inbreeding allowable, farmers will be able to manage inbreeding by making wiser mating choices. To date, this has been an under-utilized feature in the beef industry that deserves real consideration.

It should not go without mention that simple process of parent verification has a crucial impact on the accuracy of genetic evaluations and that genomic technology is the basis for this important verification.

Conclusion

Genomic testing in the livestock industry is rapidly becoming more predictable as databases grow, costs per analysis decrease, and more traits are included. Return on investment to the end user is an individualized estimate based on breeding objectives, intended use, and market needs of that specific operation.

Though not explicitly mentioned in this document, testing for genetic conditions, assuming a reasonable gene frequency, is nearly always justifiable (VanEenennaam and Drake, 2012).

However, for genomic trait tests, the answer is a bit more complicated. At the seedstock level, given the accuracy, price, and range of traits covered by current tests, testing is genetically and economically a wise decision, speeding up genetic progress and reducing risk of selecting animals that will under-perform expectations in the market place. As a management tool, genomic analysis is just beginning to be used in the dairy industry for health traits and in the foreseeable future will expand to include how the animal's own genotype interacts with the environment it is exposed to.

The combination of advanced reproductive tools and genomics is revolutionizing products offered to cattle producers, driving genetic progress at a faster pace and to heights only imagined a short decade ago. Along with this revolution, progressive commercial operations will find new ways to access higher performing genetics for their herds than what was previously possible, changing the dynamics of the relationship between seedstock and commercial cattle producers. What role will breed associations and performance recording groups play in the future of the beef cattle industry? Who will own the superior genetics in the future?

Commercial producers already have access to the same advanced genetic tools that seedstock producers have, and can use them to drive their own herd improvement in a much more aggressive way than they are doing today. Genomics combined with their own herd records gives them the opportunity to identify the best animals in their herds and then chart a course for within-herd improvement at a greater magnitude than ever possible before.

The value of genomic technology in returns to the producer is well-documented in dairy and is beginning to be proven in beef cattle as well. The value to bull-studs through reduced progeny testing is especially evident, possibly saving that industry over 90% of the cost associated with proving bulls (Schaeffer, 2006). Are bull-buyers willing to pay for this technology? In work submitted for publication in 2011, Vestal et al. (2012), found there was no evidence that bull buyers were willing to pay for DNA profile information for beef bulls available at auction. However, those authors did concede that willingness would likely change over time as buyers became more comfortable and confident in DNA test results. Indeed, much has changed since that time. The technology has improved and considerable time and resources have been invested in outreach and education efforts related to genomic technology. There is preliminary evidence that producers investing in commercial replacement females have been willing to pay $200 more per head for those that have been genomically tested (Decker, 2016). Combined with forthcoming results from Short et al., (2016) and MacNeil (2016), that suggest similar values at the commercial and seedstock level, it's becoming apparent that the value proposition for genomic testing in beef cattle is strong.

There does seem to be some fear on the part of breeders that testing may discount some animals with "undesirable" genomic results. Interestingly, Vestal et al., 2012 found that having no information (a blank box) in a sale catalog resulted in steeper discounts for some traits than having information that could be viewed as "bad". Additionally, though genomic testing may reveal some animals that have less-than-desired genetic potential, it also stands to discover others that would not have been deemed as value based on classic evaluation criteria.

At the feed yard level, widespread testing of pens of animals may not be economically advantageous at the moment in the commodity beef market, but may be justifiable in branded beef programs where guaranteeing a positive eating experience for the consumer is paramount.

Continued collection of data and development of new or improved tests focusing on traits that contribute directly to profit is important to support more definitive return on investment for the cow-calf and feedlot sectors. With fertility being the major profit driver at the commercial cow-calf level, a concerted effort needs to be made to gather service and breeding data for use in improvement and development of genomic tests. The field of nutrigenomics, which studies how differences in feed types and gut-microbe DNA interact with genotype of the animal, offers much promise in providing opportunities for efficiency and performance gains in the feed yard.

All sectors of the beef cattle industry could benefit from genomic selection under certain scenarios. Continued cooperation among producers, researchers, breeding and genomics companies, and consumers offers the best opportunity for tools that can be used to increase profits for cattlemen in the months and years to come.

Citations

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