The Role of Genetic Evaluation Technology in Enhancing Global Competitiveness

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Introduction

When we talk about global competitiveness or even just competitiveness in general, what exactly do we mean, and once defined, how do we relate this to genetic evaluation? Here are some beef and dairy examples to help us better understand:

> "The mission of the National Beef Cattle Evaluation Consortium will be to develop and implement improved methodologies and technologies for genetic evaluation of beef cattle to maximize the impact genetic programs have on the economic viability, *international competitiveness*, and sustainability of U.S. beef cattle producers."[1]

> "…Our objectives will be to: Establish and coordinate, with industry partners, the priorities for genetic evaluation of U.S. beef cattle in order to position the U.S. as a leader in this area thereby increasing the *global competitiveness* of the U.S. beef industry;…"[1]

> "…Finally, continued development of national sire selection indexes for lifetime economic merit is essential for US dairy breeders to *compete globally* in the economic production of dairy products. Such efforts are also essential to ensuring a plentiful supply of affordable dairy products for the US consumer."[2]

> "…Improve decision-making on public policy related to productivity and *global competitiveness* of the U.S. agricultural production system. Adoption of improved integrated livestock grazing management systems could improve the economic condition of livestock operators and their associated communities and land ecological conditions."[3]

Note that the fourth quote has nothing to do with genetic evaluation *per se*, but it does provide a further clue to what we mean by global competitiveness - the ability of industries to utilize technology to make money by reducing input costs and/or increasing output. The idea is that genetic change is accomplished by selecting candidates based on an index composed of EPD of economically relevant traits (ERT) weighted by marginal economic values identified by sound breeding objectives that take into account traits most closely associated with income and expense, and to do so more effectively than competitors do nationally and internationally. If we can accomplish this process, then we have the potential to produce a globally competitive product. Genetic evaluation becomes the engine to drive this process.

At its most basic, genetic evaluation is accomplished through computer services processing pedigree information and performance records for one or more traits. These records are systematically recorded and submitted by breeders of a particular breed. The choice of traits to

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[1] Mission and objectives of the National Beef Cattle Evaluation Consortium (NBCEC). http://www.reeis.usda.gov/web/crisprojectpages/195268.html

[2] Statement of issues and justification S-284: Genetic Selection and Crossbreeding to Enhance Reproduction and Survival of Dairy Cattle. http://nimss.umd.edu/homepages/home.cfm?trackID=2354

[3] Statement of issues and justification WERA1002: Managed Grazing Systems for the Intermountain West. http://nimss.umd.edu/homepages/home.cfm?trackID=1235

measure and record involves some collective judgment about what traits are economically relevant, and what traits can be routinely measured in the breeders' operations (Harris and Newman, 1994). Genetic evaluation is simply the analysis of that data using some defined statistical model(s) to arrive at estimates of the genetic merit of animals in the population. The output from a genetic evaluation is, in the case of beef cattle, an Expected Progeny Difference, or EPD, which measures the difference in performance that is expected from future progeny of a parent. Genetic evaluation procedures that produce EPD for specific performance traits should be considered a means to an end (and not the end). The desired end is an improved economy of producing consumable and desirable livestock products for the benefit of the breeder and the consumer (Garrick and Golden, 2009).

Seedstock producers are in business primarily to make a profit, as are their breeding stock customers, who produce food products. Producer's profits are influenced by consumers' demand for their products. Purchase of breeding stock involves a cost but can provide a positive influence on the functioning of the system by reducing other expenses or increasing income from output, or both. The producer will be motivated to pay more for breeding stock if given assurance that profit will increase because of these increased costs. Products sold to earn income for a breeder are primarily breeding stock (or alternatively semen). Efforts to improve the value of this product (and thus the income earned) are likely to add expenses due to the extra labor of recording data, registration and computer charges, marketing of intact animals for slaughter, and so on. The breeder will be motivated if given assurance that greater income will adequately cover these increased expenses (Harris and Newman, 1994; Harris 1998).

To summarize, genetic evaluation makes genetic improvement possible. It provides the capability to benchmark individuals within a breed, or possibly different breeds. It is a means whereby the joint investment in recording and selection can be converted to market advantage. It is possible to maximize returns in this process by recording the right traits, and make sensible use of indexing, selection and mating. To maximize the quantity and quality of data recorded so that genetic evaluation can be used most efficiently to add value a well-defined breeding structure is of fundamental importance.

Industry structures for genetic improvement

It is often useful to display the structure of a breeding program in terms of a pyramid, which also helps to reflect the size of each tier. A pyramid characteristic of pig and poultry breeding structures is composed of three tiers that direct genetic improvement (Dekkers et al., 2011). Actual genetic improvement takes place at the top of the pyramid (nucleus), followed by the multiplication of that genetic improvement to produce large numbers of purebred and/or crossbred females, which are sold to commercial farms for the production of finishing, or market pigs. From a beef industry perspective breeders who generate sires to produce sires (SS path) and dams who produce sires (DS path) are effectively the nucleus breeders.

Genetic improvement is disseminated down the pyramid, which introduces a time delay, or genetic lag (e.g., Guy and Smith, 1981). Genetic lag in pig breeding programs can range from three to five years. However, using sires at lower tiers that come directly from the nucleus allows the breeder to reduce this delay time. This allows the collection of commercial (crossbred) information for use in genetic evaluation, which helps reduce the effects of genotype x environment interaction, and aids in increasing the accuracy of genetic evaluation through the addition of crossbred relatives' records.

An alternative to the pig or poultry breeding pyramid would be that of dairy cattle, which possesses a so-called *open* nucleus structure, where animals (in this case female) from lower tiers can be brought into an upper tier by generating sons that are chosen as if they were bred in the nucleus.

Understanding the genetic structure of breeding populations helps to understand how genetic improvement is disseminated, and to identify ways to reduce genetic lag. The US beef industry does have a nucleus-multiplier-commercial structure, although not as clearly delineated as other livestock industries. Márquez and Garrick (2007, 2010) quantified the pathways of selection (sires to produce sires, SS; sires to produce dams, SD; dams to produce sires, DS; dams to produce dams, DD) in the American Red Angus database. Only 1,271 herds (30% of the total) produced SS, and only 153 of those (3.6% of all herds in the pedigree) produced 50% of the SS animals that appeared in the pedigree.

In general, an industry is at a greater advantage when genetic improvement can be concentrated in superior, or nucleus herds, especially when a breeder must select animals from another herd to introduce outside genetics with greater confidence and without loss in overall genetic superiority (Harris, 1998). How many US beef breeds can identify with confidence the nucleus and multipliers herds, or at least define a breeding structure? Do we know magnitude of genetic lag in our breeds? These are fundamental questions because they can influence the adoption of technology and determine how and where investments in technology should be made for the greatest benefit.

Uptake of genetic evaluation in the US beef industry

I have not been able to quantify the percentage of US seedstock producers who utilize genetic evaluation; it is likely not as high as it could be. Therefore, it is not apparent how well the US industry is doing in applying genetic evaluation. Some reasons for this might include:

1. The amount and quality of recording per animal or per herd varies widely. This will mean that EPD and index accuracy (if used) will vary widely among selection candidates and reduce the power of selection
2. There are opportunity costs generated when genetic evaluation is not based on sensible indexes (or indexes are not used)
3. From a simple perusal of genetic trends there is no suggestion that the US is making significantly faster progress for individual traits (or indexes) than major competitors

The question arises as to how breeders see genetic evaluation. Is it a vehicle for accelerated wealth creation, or a hurdle adding costs with little benefit? This in part reflects imperfections in the market as well as the time it takes to learn effective use of the technology. It is safe to say that the pig industry has embraced genetic evaluation as an integral step in turning recording effort into profit.

Information nucleus schemes

Genetic evaluation is a tool that converts data into information. This information forms the basis of genetic gain. The value generated by genetic evaluation depends on the information content of the dataset relevant to the breeding objective, and the effectiveness of selection. The information content is a function of the amount, quality and cost to obtain performance data. As pointed out earlier, nucleus structures are very efficient in doing this. Provided sire sampling is done wisely, they influence the entire breeding and production system.

The challenge is then to explore ways of getting the most useful data possible for a breed. A structured progeny test, called an Information Nucleus (IN; Banks, 2006, 2011), allows a breed to collect data on hard to measure traits without which its capacity for progress is greatly restricted.

There are number of traits influencing the beef supply chain that are either very expensive to measure (e.g., feed intake), or are recorded at phases and locations other than the seedstock herd (e.g., eating quality), or which take a long time to record (e.g., fertility and longevity). A breeding program that does not capture data on eating quality for example, cannot manage that trait set, let alone make genetic improvement.

The IN structure has three key elements:

1. Use of young, elite sires from diverse genetic backgrounds;
    a. Sires are progeny tested across a range of environments and for as many traits as can be measured
    b. Sires are genotyped for available markers, panels, or whole genome scans, so that the most relevant and reliable estimates of marker effects are obtained

Information Nuclei have been implemented in the Australian Sheep and Dairy industries, and recently in beef (Banks, 2011). Five Australian beef breeds (Brahman, Charolais, Hereford, Limousin, Angus) have had three or more sire intakes in their first cohort and involve recording a comprehensive set of growth, carcass, reproduction (male and female), eating quality, and docility traits.

The IN provides a way for breeds to identify and concentrate performance recording that will provide a clearer path for dissemination. When breeders and producers have relevant information about genetic merit, their combined responses could lead to faster genetic improvement for traits that drive profit. As mentioned previously, with value-based marketing, the services delivered to buyers and sellers must deliver value, so the market for services becomes more efficient as well.

A short section on indexing

I would be remiss if I did not make mention of the use of indexing in genetic improvement programs in beef cattle (or of any livestock species). It would seem logical that the ability to develop and use a selection index (Hazel, 1943; MacNeil, 2005) as part of the genetic improvement process would greatly benefit the speed at which genetic improvement in profitability can be made and also further focus attention on the importance of economically relevant traits. Garrick and Golden (2009) provide reasons why the classic Hazel approach can be difficult to implement (e.g., lack of covariances between ERT and indicator traits, lack of motivation to calculate marginal economic values, lack of industry promotion of the value proposition associated with genetic improvement). However, solutions exist to make indexing accessible. For example, MacNeil and Matjuda (2007) reported on an aggregated simulation model used to estimate marginal economic values for specialized sire lines but can also be used for more general scenarios. Through the NBCEC, Garrick (2005) developed an alternative approach using the concept of selection by simulation. Phenotypes are predicted based on current performance levels and then used to predict costs and revenue. This allows the producer to model alternative selection scenarios from a variety of breed databases[4]. Having the ability to access a common breed database would aid in the incorporation of heterosis and across-breed EPD. Some US beef breed associations do provide the ability to rank animals on a variety of indexes, but I have not been able to ascertain if these indexes are being used for animal selection and how they are being used as part of a genetic improvement program.

Closing comments

[4] See http://ert.agsci.colostate.edu/ or http://dss.ansci.iastate.edu/.

For the past ten years, I have applied a great deal of my knowledge of genetics and animal breeding to the pig, but I have never forgotten my roots – the Australian and U.S. beef industries. While I have not spent a great deal of time discussing specific aspects of how genetic improvement is made in the pig industry, much of what I have written about global competitiveness and genetic evaluation in cattle underpins what I have learned in pigs.

1. The pyramid structure for genetic improvement is very well defined. Genetic improvement takes place in PIC's nucleus farms.
    a. Genetic improvement is disseminated through well-defined tiers in the pyramid
    b. A large amount of information is collected on nucleus animals. The important point is that *every animal is recorded.*
    c. Semen from young nucleus boars is used in commercial farms so we can collect both purebred and crossbred data simultaneously so the crossbred information can be used in genetic evaluation to increase accuracy of breeding value estimation. This also helps reduce genetic lag.
        i. The crossbred data collected includes carcass, reproduction and mortality information.
    d. We also collect an enormous amount of SNP data for use in genetic evaluation.
2. All lines have distinct selection indexes
    a. While some pre-test culling occurs for certain defects, selection decisions are based on index selection *only.*
3. All of our mating decisions are accomplished with mate selection (Newman et al., 2009; Kinghorn 2011). Mate selection allows us to balance diversity (rate of change in inbreeding) with response to selection.

It is not my intention to recommend that you all become pig breeders. However, I do believe that there are lessons the beef industry can learn from pig breeders to make structured genetic improvement:

1. It is imperative that the major cattle breeds define their breeding structures and implement an Information Nucleus scheme. Among other opportunities will be greater prospects for data collection associated with hard to measure traits and also clarity in the application of genomic information as part of the genetic evaluation scheme.
    a. Decision support modeling could form the basis of a more flexible path to selection index use and also provide breeders a better feeling of controlling their own destiny, as they would have the ability to assign proper emphasis on traits of economic importance for their circumstances.
2. Utilization of genomic information of whatever form, by anyone, will depend on having relevant phenotype data with which to calibrate marker tools, whether they are individual markers or QTL, panels or whole genome scans.
3. Since breeding objectives target commercial performance, there should be a concerted effort to collect half-sib commercial and crossbred information (e.g., carcass data) to provide a basis for crossbred EPD estimation.
4. A unified database would provide the ability for higher accuracy across-breed EPD, efficient utilization of commercial/crossbred information, and also provide better decision support capabilities.
5. Implementation of a mate selection process will allow additional power to the breeding program. Mate selection will allow, for example, pre-culling of animals; consideration of a wide range of outside sires to help increase gains, lower inbreeding levels, and provide connections to outside seedstock sources that will result in better gains in the longer term, and the ability to make herd size variable by factoring in the cost of maintaining breeding

females. This can provide a path to a controlled reduction of herd size through periods of drought or financial hardship, with parallel accommodation of concerns about genetic gains.

Independent of species, to be globally competitive, we must be able to maximize the quality and quantity of data relevant to the breeding objectives we have defined per dollar invested, and then utilize the results of our genetic evaluation effectively to add value for our customers.

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