Economically Relevant Traits

A Framework for the Next Generation of EPDs

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Introduction

One key to the success of an enterprise is accurate assessment of the risks and potential returns of decision alternatives. To make informed assessment of breeding decisions breeders must have appropriate information. Extraneous and misleading information can reduce the probability a breeder's selection and mating decisions will achieve his goals.

Presumably the objective of new trait development has been to provide more complete descriptions of breeding stock (Bourdon, 1998). Some breeds now make EPDs available for nearly twenty different traits and their components such as direct and maternal effects. However the procedures used to identify the traits that are candidates for the development of EPDs have often been *ad hoc*, without scrutinizing the merit to the industry of introducing the EPD. We illustrate that many EPDs in current national cattle evaluations are extraneous. More formally these EPD add to the prediction error of the aggregate prediction of merit.

There exists a need for a framework to consider the role of traits in national cattle evaluation programs. **The aim of this paper is to provide a principle and framework to guide the process of identifying traits for which EPDs should be produced in the next generation of national cattle evaluations.** Our paradigm is based on the contribution of each trait to profit and risk.

This framework revives a foundation concept for beef cattle improvement programs that was first communicated over half a century ago. In the future, expected phenotypic expressions will be used to forecast profit and risk. We provide a vision for the evolution of genetic information systems in the beef cattle industry to increase their emphasis on business objectives.

ECONOMICALLY RELEVANT TRAITS

Many if not most traits which are measured on animals do not directly affect profit. For example, birth weight is measured not because a commercial producer gets more or less money due to the weight of a calf at birth. Rather, birth weight is used to help predict the genetic merit for other traits such as growth rate or the probability of a difficult birth. It is very difficult to assess the economic value of birth weight because larger birth weights are favorably associated with growth rates and unfavorably associated with calving difficulty. When growth rate and calving difficulty are already being considered, birth weight has no economic value.

Another example is scrotal circumference. Testicular size in normal post-pubertal bulls is not a trait with any economic value to the commercial producer. Scrotal circumference in a sire is favorably correlated to the age at which the sire's daughters will reach puberty and is, therefore, an indicator of age at puberty (Brinks, 1994). However, age at puberty is not a trait that is associated with revenue or costs. Age at puberty *indicates* the ability of daughters to conceive and have calves as two-year-old heifers. When EPDs for heifer pregnancy rate are considered, knowledge of EPDs for testicular size or age at puberty will not lead to increased progress in heifer fertility. In fact, using testicular size or age at puberty will reduce the rate of genetic progress for heifer fertility, a trait that directly influences profit.

Traits such as birth weight or scrotal circumference, that are used to indicate the merit an animal has for another trait, are called *indicator traits*. The traits that we are trying to improve we call *economically relevant traits (ERT)*. Economically relevant traits are the traits that directly affect profitability by being associated with a specific cost of production or an income stream. Indicator traits add information to the prediction of economically relevant traits.

Consider a list of traits thought to influence profit. The development of a formal selection objective requires that the economic value of each trait in the list be determined. The economic values reflect the change in profit for a unit change in the trait, when all other traits in the list are held constant. An indicator trait will have no economic value when the economically relevant traits with which it is associated are included in the list. In contrast, an economically relevant trait's economic contribution should be considered regardless of the presence or absence of any other traits in the objective.

Virtually every economically relevant trait in beef cattle production has multiple indicator traits. Table 1 contains a list of economically relevant traits and shows typical indicator traits for these economically relevant traits. Undoubtedly there are production and marketing circumstances where other traits are economically relevant.

Any trait that has a systematic genetic and/or environmental relationship to an economically relevant trait is a potential indicator trait. A non-zero genetic correlation describes only a linear relationship. Other types of systematic relationships are possible. For example, Evans, et al. (1999), reported a genetic relationship between scrotal circumference and heifer pregnancy rate, but the genetic correlation was zero. The authors devised a method for using this nonlinear relationship to enhance the accuracy of heifer pregnancy EPDs.

Table1. Proposed economically relevant traits and their indicators.

Economically Relevant Trait EPD	**Indicators[1]**
Sale Weight [2] Weaning Direct Weaning Maternal (Milk) 600 d Direct Carcass Weight Direct Salvage Cow Weight	205 d Weight 365 d Weight Carcass Weight Birth Weight Fat Thickness Cull Cow Weight
Probability of Calving Ease	Calving Ease Score Birth Weight Gestation Length
Cow Maintenance Feed Requirement	Mature Cow Weight Cow Condition Score Milk Production[3] Gut Weight
Stayability (or LPL[4])	Calving Records Days to Calving Calving Interval Milk Production[3]
Heifer Pregnancy Rate	Pregnancy Observations Scrotal Circumference
Tenderness	Amount of Intramuscular Fat Shear Force
Days to a Target Finish Fat Thickness Days to a Target Weight Finish Endpoint Days to a Target Probability of Grading Finish Endpoint	Backfat and Age at Slaughter Weight and Age at Slaughter Grade and Age at Slaughter
Docility	Docility Scores

[1]"Indicators" means traits which are measured to provide information to produce the economically relevant trait EPD. This list contains just the most obvious indicators. It is likely that different situations will be able to use other indicators.

[2]Sale weight is a category of EPDs. Different breeders will have different times at which they believe that future sales will occur for calves resulting from the current breeding decision. Each situation will require the breeder use only one of the sale weight EPDs.

[3]Milk production will most likely be measured using the maternal weaning EPD.

[4] LPL means Length of Productive Life. It is conceptually the same as stayability (Snelling et al., 1995) but expressed on a different scale.

It is usually straightforward to distinguish economically relevant traits from indicator traits. However, there are traits that are often identified as being economically relevant in the analysis of a business enterprise, such as so-called fundamentals, or key performance indicators. Some typical fundamentals in beef enterprises include feed conversion ratio and number of calves weaned per cow exposed. We do not consider these to be economically relevant traits in the context of ERT principle. These are composite traits, obtained from non-linear functions of economically relevant traits. We accept that fundamentals such as calves weaned per cow exposed may be useful for enterprise analysis but genetic progress in these composite indexes are more rapidly and predictably achieved by direct selection on a linear combination of the components of the index.

We limit our definition of ERTs to those with EPDs obtained directly from BLUP analyses (or from linear functions of BLUP analyses). This includes traits which have a linear relationship between the observed scale and an underlying liability or hazards scale (e.g., calving ease, pregnancy rate, or longevity). Economically relevant trait EPDs (and their accuracies) are applicable to individual animals and are interpreted in the conventional manner.

PROFITABLE SELECTION – HISTORICAL RATIONALIZATION FOR ERTS

The genetic basis for constructing selection indices was developed and communicated more than fifty years ago. Index construction begins by specifying the goal of the enterprise. A usual goal is increasing the level of satisfaction and this can be achieved by increasing profitability and managing risk. Having defined the goal, the next steps in the construction of an index are to identify the list of traits that influence the goal and to determine the relative importance of each of the traits in this list. Measured characteristics are then used to predict the aggregate economic merit of each candidate animal (Hazel, 1943; Hazel and Lush, 1943).

Determining the economic value of traits that influence the goal is not a trivial task. It is more difficult to achieve in beef cattle production systems than almost any other livestock species. Goals that are limited to income traits are more easily derived, as these ignore the complications of variation in costs, particularly feed costs. Evaluating feed costs is problematic, as many beef cattle graze forages that are unsuitable for other purposes except perhaps wildlife. In intensive pastoral systems such as in New Zealand, beef cattle undergo mixed grazing with sheep and the value of feed is related to the opportunity cost of forage in other enterprises which varies markedly at different times of the year. Relative economic values for traits influencing beef profitability are therefore not well characterized and probably less robust than for many other livestock enterprises.

Dr. C. R. Henderson (1951) expanded the findings of Hazel and Lush to show that aggregate economic merit could be constructed in a two step process. In the first step, EPDs were calculated, and these were combined with their economic values in a second step. With that knowledge animal breeders felt justified in calculating EPDs from measured characteristics and leaving the economic interpretation of these values to livestock breeders.

Some traits that influence the goal will not be subject to genetic influence or will contribute little to variation in profit. Such traits are typically ignored in index construction. Genetic evaluation comprises the task of predicting genetic merit for each of the economically relevant traits remaining in the objective for all the candidates that are available for selection.

In order to predict genetic merit analysts must have knowledge of factors that influence the trait in question and of relevant variance parameters. In simple cases where the trait of interest is a measured characteristic such knowledge can be obtained by collecting and analyzing field data. For example, if the trait of interest were a sale weight such as at weaning, observed phenotypic weaning weights would allow the development of suitable analytical procedures.

In practice some of the traits in the objective are not readily observed. For example, maintenance feed requirements are very expensive to measure. It is more feasible to predict maintenance feed requirements solely from indicators such as live weight, gut weight, and milk production. In this circumstance Schneeberger, et al. (1992) showed that the EPD for an unobserved trait can be readily calculated as a linear function of the EPDs for the indicator traits. Animal breeders may therefore have felt justified in producing EPD for measured traits with the knowledge that it was trivial to construct the EPD for the unobserved economically relevant traits.

Length of productive life is another example of a trait that cannot be easily observed. Measurement of this trait is further complicated by so-called incomplete records resulting from that fraction of female animals that are still present in the cowherd at the time of analysis.

In the absence of inventory recording systems, the actual length of productive life is not typically obtained and has therefore been historically difficult to predict. Accordingly, single trait analysis of individual components or indicators such as days to calving provided a sensible first step towards a goal of characterizing economically relevant traits. However, more recent research has resulted in analytical methods for predicting complex and difficult to measure economically relevant traits. For example, using methods described by Snelling, et al., (1995), Ducrocq and Solkner (1999), and more recently by Hyde (2000), it is possible to predict sustained conception rates in mature females or probable lengths of productive life, even with censored data or incomplete observations on lifetime production.

Length of productive life is associated with adult fertility traits such as days to calving and calving interval. Analytical methods to predict length of productive life can be developed from multiple trait analysis of actual productive lifetimes in conjunction with adult fertility measurements. Multiple trait analysis enables the genetic and phenotypic relationships between these traits to be estimated and used to increase the accuracy of EPDs for young animals.

The current best practice for the genetic evaluation of beef cattle falls well short of the approach originally envisaged more than fifty years ago. The vision was developed in advance of computing power, which limited lifetime reporting procedures, and analytical methods. The absence of economic values has limited the use of indexes of aggregate economic merit and poor knowledge of relationships between characters measured as selection criteria and traits in the breeding objective has precluded prediction of EPDs for many of the economically relevant traits. Sire summaries have therefore done little more than communicate the merit of animals with respect to a rapidly increasing list of indicator traits. However, focusing our research efforts on the few remaining economically relevant traits in table 1 for which there is not yet an EPD will bring us to a more useful approach to selection.

PROPOSED ERTS AND THEIR INDICATORS

The economically relevant traits in table 1 are meant to be a general, but not exhaustive list that would apply to many typical production circumstances. Evaluating the selection of bulls to produce replacement females will use a different set of ERT EPDs than selecting terminal sires. Furthermore, every producers' ERT are not necessarily included in table 1. For example, a high mountain producer (typically above 7,000 feet) may benefit from an EPD for incidence of brisket disease (pulmonary edema) a common cause of death loss. Some producers in tropical environments can benefit from a tick resistance EPD. This EPD would be economically relevant because of the cost of treating susceptible animals to control ticks.

An EPD for sale weight is essential in all production systems. Cow-calf producers have several alternatives for the age when they market their calves. Some producers market at weaning, others at a year of age, and yet others at harvest. For most breeders only one of the sale weight EPDs will be economically relevant. In 1999 over 80% of calves were sold at weaning. It is likely that few of the producers of these calves were given a premium for calves with superior post weaning gain or carcass weight. To maximize profit and minimize risk, these producers should consider only the weaning EPDs (direct and maternal) and their associated accuracies. Data on many of the indicator traits are currently recorded.

Cow-calf producers incur losses and veterinary/labor costs when cows have difficult calvings. Data that can be used to produce the probability of calving ease include calving ease score, birth weight, and gestation length.

The costs associated with feeding and maintaining cows accounts for a large proportion of expenses. Genetic evaluation of cow maintenance feed requirement does not currently exist; although, efforts are underway to develop such an EPD (Evans, 2000; MacNeil and Mott, 2000). Mature weight and milk production (in the form of the maternal weaning weight EPD) are used as indicators of maintenance feed requirements. It has been shown that cows with higher milk production have increased maintenance requirements, even when dry. Fatter cows have lower maintenance requirements than lean cows with the same mature weight. Therefore, condition score may improve the accuracy of the maintenance EPD by partitioning energy requirements into fat versus lean tissue requirements. A large portion of maintenance energy is used to maintain visceral organs (e. g., liver, intestine, etc.). It has been proposed that gut, or gut component weights may be useful indicator traits for cow maintenance EPD. These may be obtained by live animal ultrasonic or carcass observations.

The two economically relevant female fertility traits are heifer pregnancy rate (Evans et al., 1999) and stayability (Snelling et al., 1995). Heifer pregnancy rate predicts ability to conceive at a year of age. Stayability predicts ability to remain in the herd producing calves after having produced a calf as a two-year old. Data used to predict heifer pregnancy rate are pregnancy observations (or calving records) and may include scrotal circumference on related male animals. Indicators for stayability include calving records (did the cow calve in a given year), cow weight, days to calving (or calving interval), and milk production (maternal weaning weight). Data on some of these indicator traits already exists in many databases so genetic evaluation for these reproduction ERTs is currently feasible.

The length of time required to produce a harvest-ready animal is an economically relevant trait for the feeding and finishing phase. For producers that are selling weanling calves these traits are economically relevant if sale price reflects the merit of the calves for these traits. Animals are fed to a variety of finish endpoints including target backfat level, target weight, or target quailty grade. For animals fed to a target .4 inch backfat the logical choice of indicators would be backfat at harvest and age at slaughter. For a weight target endpoint age and weight at slaughter are indicators. Marbling score, including ultrasonic measures, with age at slaughter are indicators for finishing programs with quality grade endpoints.

An EPD for the time it takes to finish animals substantially simplifies the calculation of differences in costs to finish progeny of alternative sires. Time to achieve alternative finish endpoints will account for some of the differences in feed consumption to finish endpoints. There is likely to be additional variation in feed consumption but collection of individual feed consumption data is not currently practical. The days to target endpoints is a pragmatic compromise

How to use ERT to Predict Profit and Risk

It is likely that many, or even most producers use a heuristic approach to selection that often involves a mix of truncation selection and an intuitive emphasis on different traits that is analogous to an ad hoc selection index weight. Developing sire summaries with economically relevant traits become even more important when this approach to selection is used. There are three sources of the error that can be reduced in heuristic indexes, or more correct selection indexes, by sire summaries with only economically relevant trait EPDs. The first source of error occurs when a non-zero emphasis is placed on an indicator trait EPD, especially when the economically relevant trait EPD is in the sire summary. The indicator trait EPD cannot add more information to the selection process, so any emphasis on the EPD adds only prediction error due to the prediction error covariance. The literature contains examples of this type of error occurring in selection index procedures (e.g., Schneeberger, et al. 1992) such as BreedObject.

The second source of error occurs when an indicator trait EPD is available but not the EPD for its economically relevant trait. The producer often over- or under-emphasizes the value of the indicator trait EPDs ability to predict its economically relevant trait. By having an economically relevant trait, even when it is solved using only information from the covariance with an indictor trait, the producer has access to an accuracy value more appropriate for assessing risk of the decision.

The third source of error is often called information overload. Requiring producers to wade through an overwhelming amount of often extraneous and incomplete information will load to poor decisions. It is likely that most producers realize that without a detailed technical understanding of the relationships between traits and profit their decisions based on indicator traits are at best imprecise. We should anticipate that they will often not invest that necessary effort, largely out of frustration.

Genetic evaluation programs have attempted to meet client's expectations by providing EPD for traits perceived to be of economic importance. While this has increased the number of EPD available, breed associations and genetic evaluation providers have not efficiently exploited data reduction techniques such as ERT or selection indexes. The result is a number of EPD that on the one hand provides a description of an animals' genetic merit but does not attempt to correlate these with profit. Alternatively, the use of selection indexes (and the implementation of ERT in the decision-making framework) will require more information, but it is likely that the cost of collecting that information will be small in relation to the increased potential for profitability and efficiency in an integrated decision-making platform.

Decision Support Systems

Economically relevant traits will be delivered to industry in the form of Expected Progeny Differences (EPD). However, to be used in an optimal manner, ERT-EPD should be used in a decision-making framework incorporating the breeder's/producer's desires for longer-term viability of their production system. Thus, their use must be integrated into a framework that simultaneously incorporates technical, logistical and costs issues. Decision support tools will be required to achieve this task.

Decision support systems (DSS) are computer systems that assist the user in complex problem solving or decision-making. They are an integrated approach to the age-old problem of helping people make better decisions. Decision support systems typically have quantitative output and place emphasis on the end-user for final problem solving and decision-making (implementation). Jenkins and Williams (1998) and Newman and Stewart (1997) summarized examples of DSS within the animal production area.

Table 2 provides some examples of decision support tools developed for use in beef cattle breeding and production (this is not an exhaustive list, but provides a general overview of what is available). Many applications have taken advantage of distributed information technology environments through the use of WWW-based information dissemination. Table 2 describes increasingly greater levels of complexity toward integrated decision-making in livestock production as you move from top to bottom. Achievement of total integration depends on the level of complexity the user requires, because a greater amount of data is needed.

Table 2 Examples of beef decision support tools to address breeding program design issues

Examples of decision support tools	**Example(s) programs, references, contact information**	Distributed	Expert Intervention required?
Sire summaries / sire selectors Developed and disseminated by breed associations in cooperation with genetic evaluation provider Provides EPD, accuracies, pedigree information	www.studyweb.com/links/2489.html	Paper and WWW	No
Crossbreeding program design Allows comparison of a large number of breeds and designs Incorporates combinations of environments, management schemes and marketing arrangements in industry	HotCross (www.beef.crc.org.au/Commercialization) Simumate (mike@larrl.ars.usda.gov) CrossChoice (web.missouri.edu/~anscbeef/expert.html) Newman and Stewart (1997)	As part of workshop diskettes from developers download from WWW	No
Breeding objectives tools (combine production information and breeding values)	BreedObject (www.breedobject.com)	Consultant's report and WWW-based	Yes

Facilitates formal definition of breeding objective Derives appropriate selection index for a given breeding objective from available genetic evaluation and production system information Applies index to rank animals on profit		catalogues	
WWW-based sire selectors with indexes Utilises elements of on-line sire selectors and breeding objective software Allows commercial producer to directly target particular markets	Australian Angus Society (www.angusaustralia.com) New Zealand Charolais Society (sireselector.massey.ac.nz/)	WWW WWW	No
Integration of breeding program and management decisions Integrates genetics, nutrition, growth, body composition, reproduction and management to simulate and predict beef cattle life-cycle production	Decision Evaluator for the Cattle Industry (DECI) Tom Jenkins (jenkins@marcvm.marc.usda.gov)	CD-Rom	No
ERT effects on profit allows user to model cash flow of production system with user-specified ERT, herd structure information and income and expenses	ERT Profit/Modelling Prototype Bruce Golden bgolden@ops.agsci.colostate.edu	WWW	No
Tactical Optimisation of Breeding Programs Balances technical, costs and logistical issues in breeding programs User-driven through specification of desired outcomes Uses mate selection to incorporate decisions on animal selection and mate allocation	Total Genetic Resource Management (TGRM) (www.beef.crc.org.au/Commercialization)	Consultant's report	Yes

CONCLUSIONS – WHAT NEEDS TO HAPPEN NEXT

The approach recommended in this paper reflects a long-term vision that is consistent with the scientific innovators of the 1940's. First, EPD should be calculated for all economically relevant traits. This involves BLUP analyses of existing data. Concurrently, EPDs for indicator traits that are not themselves economically relevant traits, should not be subject to publication and we should focus our research and development efforts to produce EPD for the few traits in table 1 which are not currently available.

Economically relevant traits EPD give us the opportunity to improve the delivery of decisions analysis software and procedures. By having a sensible standard set of trait to parameterize decisions analysis it is possible do develop a host of computer-based software that will calculate the economic value of economically relevant traits. It is clear that public investments in this type of development effort will have a very high potential for return. We should make a host of software tools accessible via the web, in association with electronic sire or animal summaries. These would allow animals to be presented in index order, and may allow bull buyers to make informed decisions about the relative impact of prospective sires on their enterprise profitability and risk.

Economically relevant traits and business decisions should be integrated into a framework that is an integral part of the overall business strategy, and not merely play a supporting role. Breeding program decisions are long-term investments and cannot be made in isolation of other important business decisions.

Finally, systems that are better than EPDs should be developed for presentation to bull breeders and bull buyers. Breeders and buyers are not interested in EPDs as much as they are interested in the actual phenotypic performance of future offspring. In the simplest setting, EPDs are adequate for this task. However, with added complications such as maternal influence, inbreeding, heterosis in crossbred systems, and variation due to production and management circumstances, the EPD is somewhat limiting. Computer-based systems should predict the phenotypic performance of offspring from various mating options. Such look ahead mate allocation strategies, in concert with new analytical techniques such as from evolutionary algorithms will facilitate adoption and add considerably to the benefit that can be harvested from existing evaluation systems.

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