ECONOMIC ASPECTS OF THE CHOICE OF A BREEDING OBJECTIVE

Aspectos economicos de la eleccion de un objectivo de crianza

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The selection goal or breeding objective is the starting point for any selection program. Yet as indicated by Brascamp (1978), defining the breeding objective has received the least attention of any of the stages of optimizing breeding schemes. When the breeding objective is a single trait, it is complete when the trait to be improved is chosen. The inclusion of multiple traits in the selection objective requires some form of relative weighting of the traits. Net returns or profit provide a reasonable basis for determining these relative weights for many producers.

Thus, weighting traits by their effect on profitability should provide the best genetic basis for improving long term profitability. The aggregate genotype (H) proposed by Hazel (1943) was the first major attempt with animals to use an economic basis for multitrait selection. The selection goal was defined as linear function of breeding values where each trait was weighted by its economic value. The economic value was defined as "the amount by which net profit may be expected to increase for each unit of improvement in the trait" (Hazel, 1943).

The strict use of H for multitrait selection goals has been limited by the following:

a) profitability often cannot be described by a linear function,
b) economic importance of some trait is difficult to determine for breeding goals which are reasonably complete,
c) economic importance of some traits is not linear over the range of the traits,
d) economic importance of traits varies with different environmental conditions.

Additional problems and possible alternative approaches have been discussed [Gibson, 1976; Harris, 1970; Miller and Pearson, 1979; Morris, 1977; Pearson and Miller, 1981; Wilton and Van Vleck, 1968].

While Hazel (1943) originally proposed the aggregate genotype for within-breed selection, a similar function could be used as a basis for crossbreeding or breed comparisons and thus the broader term of breeding objective seems appropriate. H will be used in this paper to describe any linear function of genotype values weighted by their economic values, while breeding objective will be used to refer to any function used as a basis of genetic evaluation.

Before discussing specific aspects of choosing the traits to be included in the selection goal and of estimating the economic values used, several general concepts need to be mentioned.

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Choice of prices - Prices of concern for genetic evaluation are those several years in the future when the resulting generations of offspring will produce. Selection choices between alternative individuals are dependent on the relative prices of the inputs and outputs and consequently are practically unaffected by the general inflation of prices common to all inputs and outputs. Conversely, decision relative to the size and intensity of selection programs depend more on the absolute value of the costs and expected gain. Thus, for purposes of developing a breeding objective, choice of prices reduces to determining the extent of long run changes in price relationships (still no easy task).

No one pattern of price changes is reflected in all inputs and outputs. Fixed costs of facilities, equipment, land and labor, and milk price (at least in the U.S.) have tended to be more influenced by inflationary pressures than by cyclical changes. In contrast, meat, egg, and feed grain prices exhibit a greater cyclical pattern while still being influenced by inflation. When choosing prices to be used in deriving the breeding objective, previous price trends must be combined with a prediction of whether the trend will continue, intensify, or weaken. The role of political intervention in prices makes this a difficult task. For example, over the past several years in the U.S., milk surpluses have been growing, yet milk prices have continue to rise and the butterfat differential has risen even faster than the milk price! This, however, cannot be a long term trend, as consumers are unwilling to pay a higher price in the market place and continue to support the price with government subsidy.

Frequent changes in the price relationships used in deriving breeding objective (especially in a cyclical fashion) can have a devastating effect on genetic change. In contrast, using the same breeding objective over periods of major shifts in price relationships will produce maximum genetic change but not necessarily in the correct traits or even in the correct direction. Thus, it seems that economic values should be changed infrequently, after substantial evidence for changing price relationships has accumulated. The correlations [Balaine et al., 1981] between estimates of profit using widely divergent prices over a 15 yr. period (r> .98) provide further support for this conclusion.

Discounting - Discounting has been used to express results which occur at different times equitably by accounting for the cost of money. The use of discounting in evaluating animal breeding plans has become fairly routine over the past 10 years. Smith (1978) has discussed the proper interest rate to use in discounting and has suggested the use of the inflation free interest rate of 3 to 5%. When the expected response is more uncertain, there seems to be some justification for a higher discount rate [Pearson and Miller, 1981]. Another question which needs to be considered in using discounting is the length of the planning period. Cunningham and Ryan (1975) have shown that with moderate discount rates (10%), a planning period of 10 to 15 yrs. is adequate for demonstrating differences which exist.

Economic point of view - It is important to establish whose economic benefit is being maximized in the selection process [Harris, 1970; Moav, 1973; Wilton et al., 1978]. Decisions which maximize net income at the producer level are not always ideal from other points of view (consumer, industry). For example, when a product surplus exists, increased production is undesirable from a national or industry point of view, however, increased production by the individual producer may still have a positive economic impact on his operation.
This is particularly true if he is small and has no effect on the price paid. This situation currently exists in the U.S. dairy industry [Miller and Pearson, 1979]. When developing a breeding objective from the individual producers point of view, the prices received could be adjusted for the impact of the higher production. This would alleviate some of the conflict between producer and consumer but would no longer maximize profit of the individual farm in the short run. The option of minimizing cost/unit of product could also be considered.

CHOICE OF TRAITS

A strong relationship between the breeding objective and changes in profitability is highly desirable. This implies that all traits which are associated with profitability of the animal should be included in the breeding objective. Including all economically important traits is in agreement with the conclusion of Gjedrem (1971). In most species, this would yield a breeding objective with a large number of traits. Using a complete breeding objective has the disadvantage of requiring estimation of a large number of genetic parameters, mainly covariances with the traits in the selection criteria, and economic values. Data to estimate these genetic covariances is frequently limited. If these parameters cannot be estimated accurately, the resulting selection will produce less than maximum change in profitability [Harris, 1964; Vandepitte, and Hazel, 1977].

A more practical approach might be to include in the breeding objective any trait which accounts for a significant proportion (perhaps 10%) of the variation in profit. Miller and Pearson (1979) have listed a number of the invalid reasons which have been used to justify omitting a trait from the selection objective.

A second major question must be addressed. What measure of the traits will be used? This has several ramifications: 1) will traditional traits be used or will inputs and outputs be used (i.e., days open vs. feed, labor, semen, etc.), 2) what units of expression will be used (i.e., per animal, per day, per gestation, or per unit of product), 3) what measure of the trait will be used (i.e., days open, number of services, or length of the breeding period).

The use of a Hazel type selection goal would seem to imply the inclusion of traditional traits while use of a profit function to form the selection goal [Harris, 1970; Gill and Allaire, 1976; Moav, 1973] would favor inclusion of inputs and outputs.

The units of expression should reflect the constraints faced by the producer. For example, if the number of stalls is fixed, the producers income is maximized with the highest profit per animal per time period and expression of traits on a per time period basis is indicated. If the number of farrowing pens were the limiting facility, expressing traits on a per farrowing basis would be indicated. One advantage of expressing the breeding objective on a per time basis is that fixed costs can be virtually ignored.

The question of which measure of a trait to include is theoretically easy to answer but in a practical situation is more difficult. Theoretically, the measure which explains the most variation in profit should be included. The true economic impact of a unit change in the breeding value of a trait can be difficult to estimate accurately especially if the trait is highly influenced by environmental conditions. Thus, in most situations, the measure of the trait to be included is chosen rather arbitrarily with a preference for the measure with the highest heritability and the most reasonable distributional properties.
Traits which can be accounted for fairly accurately by other traits need not be included in the breeding objective. For example, if the variation in feed intake is accurately accounted for by a function of weight, weight change, milk and fat production \( R^2 = .9, \) Coffey, et al. 1982], then one gains very little by also including feed intake. This is particularly true if feed intake will not be included in the index. However, if there are genetic differences in feed needed to produce one kg of 3.5% fat milk or if one of the other traits is not included, then feed intake should be included in the breeding objective. If measured accurately enough, there are usually genetic differences in biological relationships. However, often the differences are small enough that gains do not justify their inclusion.

**ESTIMATION OF ECONOMIC VALUES**

Long term stable price relationships provide the economic base for estimating the economic weights for the traits in the breeding objective. It is also clear that for the breeding objective to reflect profit, expenses as well as income will need to be incorporated. This can be accomplished by incorporating cost traits into the aggregate genotype with negative economic values or by accounting for the additional cost in deriving the economic value for the income generating traits.

Several approaches have been used to determine economic value [Gibson, 1976; Miller and Pearson, 1979; Morris, 1977, Pearson and Miller, 1981, and Ronningen, 1978]. In Hazel's (1943) initial examples he described the process for several traits which had direct relationships to inputs and outputs. Economic values were simply functions of the prices and inputs and outputs. A second approach is to calculate the regression of profitability of individual animals on the traits in the breeding objective [Andrus and McGilliard, 1975; Nordskog, 1960; Pearson and Miller, 1981]. A third approach is to use profit per day as a single trait breeding objective [Gill and Allaire, 1976; Lin and Allaire, 1977]. This approach avoids many of the problems associated with expressing the breeding objective. However, with this approach, the genetic covariances between the breeding objective and the traits in the index must be reestimated each time prices are changed. This approach has been a productive research tool, but there is little evidence that it provides a workable method for use in practice. Several additional approaches have been used which focus on the profitability of the firm. Gibson (1976) used linear programming to estimate the economic weights for the breeding objective. The major change associated with this approach was that economic value was redefined to "the amount by which profit of the firm may be expected to increase for each unit of a trait of a single animal." Several forms of deterministic simulation have been used to adjust the gross returns for the additional costs on a herd basis (Morris, 1977). It would appear that this approach may be useful for beef, where there is a tendency to search for the correct genotype to fit a particular set of environmental conditions rather than to practice directional selection for a common breeding objective.

The method of deriving economic values originally alluded to by Hazel (1943) is intuitively very appealing. That is, to determine the economic impact of one unit change in a trait by summing the value (cost) of all changes in inputs and outputs. This method has the advantage of being 1) simple, 2) based on established biological relationships (for example, the amount of feed necessary to produce an additional kg of milk or a kg of meat), and 3) reasonably free of the variance - covariance structure of the traits in the breeding
objective and profit. However, there are a number of cases where this method will not work: 1) where there are no established biological relationships between the traits and corresponding inputs and outputs (for example, the relationship between sales price of breeding stock and breeding values for production traits or the relationship between inputs and outputs, and incidence of disease), or 2) where the relationship between traits in H and inputs and outputs is complex as is often the case with a fairly complete selection objective.

When the Hazel method is not possible, the estimation of economic values is probably best accomplished by the regression of profit on the traits in H [Andrus and McGilliard, 1975; Nordskog, 1960; Pearson and Miller, 1981]. Computationally, this method provides a simple approach to determining economic values. However in practice, a number of problems arise. The "traits" necessary to calculate profitability accurately are recorded in very limited number of specialized herds or flocks (usually experimental herds). These herds do not necessarily employ the same management practices used in the field. Also, these data sets represent a limited number of cows and herds. Given these conditions, it is not difficult to imagine a variance-covariance structure which is quite different from the population as a whole. Multiple regression estimates are very dependent on the traits included. An incomplete breeding objective could yield economic values estimated by multiple regression which are quite misleading (unique to the management conditions represented in the data set). Thus, using multiple regression to estimate economic values works best when, 1) the data used are representative of the population for which they are to be used, 2) the variance-covariance structure is similar to the whole population, and 3) a fairly complete breeding objective is employed.

Multiple expression of traits - In calculating economic values of traits, it is important to consider the number of times the trait is expressed in the animal's life. Some traits are expressed only once (for example, slaughter weight or daily gain). Others are expressed more frequently (for example, lactation milk yield, or days open). If the number of times expressed is not attributed to genetic groups, the basic economic value can be multiplied times a discounted number of occurrences. However, more productive animals tend to have a greater opportunity to express the trait. The net result of genetic variation in stayability is to produce non-linear economic values for the traits affected. This effect is similar to the non-linear effect resulting from variation in a number of offspring described by Ronningen (1978). The possibility of developing quadratic indexes [Ronningen, 1971; Wilton and Van Vleck, 1968] is one approach to this problem. In the case of stayability, the magnitude of the problem is minimized by the small amount of genetic variation present.

Multiple use animals - In most species, breeding animals have several different income producing functions (dairy-milk, beef, and breeding stock; sheep-wool, meat and breeding stock). The economic value of each trait is not constant for the different income producing functions. Thus, in these situations, the breeding objective must employ a weighted average of the economic values for the different income producing functions. In determining the weighting system to be used it is critical to determine if the income producing functions are mutually exclusive or if animals will contribute to more than one of the income producing functions. James (1978) has proposed a method of subindexes which take account of the economic returns and future generation gains. This method accounts for the different economic importance of the traits in the two sexes and uses discounting
to weight current and future gains equitably. This method has a great deal to offer once the basic net return per unit is established.

A pragmatic approach to developing an economic objective - Developing breeding objectives for use by producers often employs a pragmatic approach based on estimates or guesstimates of relationships between traits and inputs and outputs originating from various sources. Pearson (1982) has developed economic weights for a limited breeding goal including milk, fat percentage, and type conformation for use by purebred dairymen to select sires for use in the herd. Income from production and sales of breeding stock were considered.

In most markets in the U.S., milk is priced in the following way:

\[
milk price/kg = base price + fat differential \text{ (Fat} \%-3.5)\]

where, base price = the price per kg of 3.5% fat
fat differential = changes in price associated with 1% change in fat percentage.

This formula can be rewritten as the price for 0% fat milk and the fat differential times the fat percentage. Then the value of milk is:

\[
milk value = milk (kg) \times [\text{price}^0_{\%} \text{ fat} + \text{fat differential} \times \text{fat} \%]
\]

\[
= milk (kg) \times [0.1775 + 0.0375 \times \text{fat} \%]
\]

From this formula it is obvious that the economic value of milk and fat percentage cannot be precisely written in a linear form. A linear approximation can be used if different economic values are assumed for herds with different levels of production. Dommerholt et al. (1978) have estimated the feed cost for the components of milk. From these figures one can calculate the percentage income over feed cost for milk and fat (78% and 68%). In addition there are indications in the literature that health and reproduction costs increase with increasing milk yield [Shanks et al., 1978] and decrease with improving components of type [Gilmore, 1977]. No change has been reported relative to fat percentage. Health and reproduction costs were assumed to increase $.01/kg milk and decrease $2.00/pt. of type.

Economic values can then be calculated for milk, fat percentage, and type for herds of different production levels (milk and type are unaffected by herd production level).

\[
\begin{array}{l}
\text{Milk} = 0.1775 \times 0.78 - 0.01 = 0.1248/\text{kg.} \\
\text{Type} = 2.00/\text{pt.} \\
\text{Fat} _{5000 \text{ kg}} = (0.0375 \times 0.68) \times 5000 = 127.5 \\
\text{Fat} _{7500 \text{ kg}} = (0.0375 \times 0.68) \times 7500 = 191.25 \\
\text{Fat} _{10,000 \text{ kg}} = (0.0375 \times 0.68) \times 10,000 = 255
\end{array}
\]

Assuming standard deviations of transmitting ability of 250 kg .09% and .7 for milk, fat percentage, and type, and 1.5 discounted lactations per cow would yield the following economic weights (per standard deviation) for animals entering the milking herd.
In the herds being considered, some animals are sold as breeding stock. Ruff et al. (1982) have estimated the partial regression coefficients of sale price on predicted difference of the sire for milk, fat percentage, and conformation [$.53, $958., and $266. for cows and $.29, $1112., and $93. for heifers]. However, the standard deviations of the predicted difference in this data set were different from those normally assumed for the population as a whole [307 kg, .104%, .51 for the cows and 287 kg, .105%, and .46 for the heifers]. Thus the partial regression coefficients were multiplied times their respective standard deviations and results for cows and heifers averaged to obtain the economic values (on a standard deviation basis) for breeding animals sold.

\[
\begin{align*}
\text{Milk} & \quad \frac{.529 \times 307 + .288 \times 287}{2} = 122.5 \\
\text{Fat Percentage} & \quad \frac{958.5 \times .104 + 1112.9 \times .105}{2} = 108.2 \\
\text{Type} & \quad \frac{266.5 \times .51 + 932 \times .46}{2} = 89.1
\end{align*}
\]

Thus, it is obvious that type is substantially more important for a dairymen selling breeding stock than for a commercial producer. Part of the difference in these goals may be due to the influx of investor money due to current tax laws. Using the economic values for production for the 7500 kg herd, the following economic weights resulted for different percentage of animals being sold as breeding stock.

<table>
<thead>
<tr>
<th>Percentage of Animals Sold As Breeding Stock</th>
<th>Economic Values(^a)</th>
<th>Relative Economic Values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milk</td>
<td>Fat Percentage</td>
</tr>
<tr>
<td>0</td>
<td>46.8</td>
<td>25.8</td>
</tr>
<tr>
<td>5%</td>
<td>50.6</td>
<td>29.9</td>
</tr>
<tr>
<td>10%</td>
<td>54.4</td>
<td>34.0</td>
</tr>
<tr>
<td>100%</td>
<td>122.5</td>
<td>108.2</td>
</tr>
</tbody>
</table>

\(^a\)On a standard deviation of predict difference basis.

The economic values presented above would need to be divided by the population standard deviations presented earlier to be used directly. It is obvious from the combined economic values (5 and 10% animals sold for breeding stock) that the resulting values are affected not only by the percentage of the animals involved but also by the relative magnitude of the separate economic values (0% and 100%).

This example is intended to demonstrate some of the problems involved in estimating economic values in a practical situation. The methods of estimation used are rather unsophisticated and serve only as basis for selection until more refined values can be estimated. The question of how to incorporate differences in stayability (discounted lactations per cow) has not been addressed and continues to be an unresolved problem.
SUMMARY

Definition of a breeding objective is discussed with regard to choice of prices, discounting, economic point of view, choice of traits to be included and estimation of economic value of traits. Prices need to be projected several years in the future. Traits which exert a significant impact on profitability should be included in the breeding objective. Economic values based on biological relationships are preferred, however, the regression of profit on the traits in the breeding objective may provide a more plausible approach for fairly complete breeding objectives. An example with multiple income producing functions is used to demonstrate some of the problems encountered in defining a breeding objective. Considering multiple generations with appropriate discounting techniques appears desirable if basic estimates of economic value can be calculated.

REFERENCES


