# ACCOUNTING FOR FEED COSTS IN IMPROVEMENT PROGRAMMES FOR GRAZED DAIRY CATTLE

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## INTRODUCTION

Modern dairy cattle improvement programmes have a profit focus. Given a goal based on profit, defined as income less costs, it is apparent that the traits in the selection objective should take due accord of milk revenue, beef revenue, replacement costs, health costs, reproduction costs, and feed costs. The inclusion of milk and beef revenues in the selection objective is a straightforward process. Accounting for replacement, health and reproduction costs is problematic, partly due to the absence of suitable measurement criteria to allow the ranking of animals for the relevant components of these attributes. With respect to feed costs, these are well known in production circumstances where feed is purchased. However, determining feed costs in grazing circumstances is more difficult. This paper presents an approach for valuing feed from its average revenue and shows the equivalence of this explicit approach to a published alternative. It is then further suggested feed intake be explicitly included in the objective.

## THE COST OF GRAZED FEED

First, consider an enterprise-based profit function for a pastoral dairy farm

$$\Omega = \pi \times S - \delta$$

where $\Omega$ is the enterprise profit, $\pi$ is the net farm income per production unit, S is the farm scale or number of production units, and $\delta$ are fixed enterprise costs.

Given some trait q to be included in the selection objective, the relative economic value for q is required, defined as the change in enterprise profit per unit change in trait q, with all other traits held constant. This is the partial derivative of $\Omega$ with respect to q.

$$\partial\Omega/\partial q = S \times \partial\pi/\partial q + \pi \times \partial S/\partial q - \partial\delta/\partial q$$

In common with many other authors it is assumed that farm scale is a management decision determined by equity, labour, interest rates and risk, unrelated to small changes in production traits. Accordingly, $\partial S/\partial q = 0$. Further, assume $\partial\delta/\partial q = 0$ as, by definition $\delta$ includes items unrelated to the farm scale or productivity. Costs associated with a production unit will be included in the definition of $\pi$. Thus,

$$\partial\Omega/\partial q = S \times \partial\pi/\partial q$$

Since the multiplier S will be the same for all traits in the objective, the relative economic values can be simply defined as the partial derivatives $\partial\pi/\partial q$. Thus the consideration of profit can be "scaled" to a single production unit.

Define a production unit based on a unit of land, such as one hectare.

$$\boldsymbol{\pi = (M+B-C) \times (F+x)/I - H - x \times P} \qquad [1]$$

where $\pi$ is net farm income per hectare, **M** is the per cow revenue from milk sales, **B** is the per cow revenue from beef sales, **C** is the costs per cow, excluding feed costs, **F** is the average feed kg dry matter (DM) utilised per hectare including grown forage and purchased supplementary feed used according to normal farm practice, ***x*** is additional kg DM feed (on a per ha basis) bought into the farming system, **I** is the total feed intake per cow (kg DM/cow/year), **H** are fixed costs per ha, and **P** is the cost in $ per kg DM of additional feed.

Note that **(M+B-C)** is income above fixed costs expressed per cow. The stocking rate (**R**) of milking cows will be determined by the total amount of feed utilised per ha (**F+*x***) divided by the feed requirements per cow (**I**). Thus **R=(F+*x*)/I**. Note that ***x*** denotes "bought in" feed in the form of any or all of: concentrates; nitrogen or phosphate fertilisers; pasture renovation; drainage; maize silage; replacement grazing off-farm; wintering of dairy cows off-farm; or purchase of additional land.

Consider two alternative scenarios in which elements of this profit function could be defined.

1. Fix $\boldsymbol{x} = \mathbf{R}\times\partial\mathbf{I}/\partial q$, the additional intake required per ha as a result of a unit change in trait q. This assumes constant stocking rates, with farmers using management techniques to introduce additional feed to exactly meet any new feed requirements from, for example, more productive or heavier cows.
2. Fix $\boldsymbol{x} = 0$, implying that no additional feed is bought into the system. In this case, any increase in feed requirements per cow must be met by a reduction in stocking rate. On an average New Zealand farm, the current rate of genetic improvement would require a reduction of almost 1% cows from the herd every year. Annual reductions in stocking rate seldom occurs in practice because of increases in **F** (and/or ***x***). Note from the definition of **F** that assuming $\boldsymbol{x}$=0 does not imply a farm system is 100% grazed forage.

Scenario 1 is rescaling to keep a fixed number of animals per farm whereas scenario 2 is rescaling to keep total feed supply fixed. Visscher *et al.* (1994) used scenario 2. McArthur (1987) set ***x*** to 0 but varied **F** with stocking rate and genetic improvement.

**Calculation of economic values.** Differentiate the profit function [1] with respect to the variable q.

$$\partial\pi/\partial q = [(\mathbf{F}+\boldsymbol{x})/\mathbf{I}] \times \partial(\mathbf{M}+\mathbf{B}-\mathbf{C})/\partial q + [(\mathbf{M}+\mathbf{B}-\mathbf{C})/\mathbf{I}] \times \partial(\mathbf{F}+\boldsymbol{x})/\partial q - [(\mathbf{M}+\mathbf{B}-\mathbf{C}) \times (\mathbf{F}+\boldsymbol{x})/[\mathbf{I}^2]] \times \partial\mathbf{I}/\partial q - \partial\mathbf{H}/\partial q - \mathbf{P}\times\partial\boldsymbol{x}/\partial q$$

There are five additive terms, each term involving a derivative with respect to q. Assume $\partial\mathbf{H}/\partial q = 0$ as the per hectare costs (water supply, weed & pest, fencing, maintenance fertiliser) **H** are assumed constant. Thus the numerical value assumed for costs per hectare has no affect on the derivatives, economic values or relative economic values. This implies that accounting for the opportunity cost of capital invested in land has no affect on the economic values, although it would obviously affect actual profit per unit of land.

Economic values for profit in the current lactation will now be derived, ignoring the complexities of herd age structure, gene flow and discounting of returns.

*Scenario 1.* Purchasing additional feed to support greater feed requirements of higher producing cows. That is, $\boldsymbol{x}$ is defined to equal the change in intake such that $\partial \boldsymbol{x}/\partial q = \mathbf{R}\times\partial\mathbf{I}/\partial q$. Recognising **C** and **F** are constants, defining $\mathbf{(F+}\boldsymbol{x}\mathbf{)/I = R}$ and $\mathbf{(M+B-C)/I = A}$, the average revenue of a cow per kg DM consumed (since **M+B-C** is a "net" income per cow and **I** is the kg DM consumed per cow) allows the following simplifications:

$$\begin{aligned}\partial\pi/\partial q &= \mathbf{R}\times\partial\mathbf{(M+B)}/\partial q + \mathbf{A}\times\mathbf{R}\times\partial\mathbf{I}/\partial q - \mathbf{R}\times\mathbf{A}\times\partial\mathbf{I}/\partial q - \mathbf{P}\times\mathbf{R}\times\partial\mathbf{I}/\partial q\\ &= \mathbf{R}\times\partial\mathbf{(M+B)}/\partial q - \mathbf{P}\times\mathbf{R}\times\partial\mathbf{I}/\partial q\end{aligned}$$

Should one wish to express the economic values on a cow basis, the above expression would be divided throughout by the number of cows per ha (**R**). Thus, using the prime ($\pi$`) to denote net income expressed on a per cow basis,

$$\partial\pi`/\partial q = \partial\mathbf{(M+B)}/\partial q - \mathbf{P}\times\partial\mathbf{I}/\partial q \qquad \textbf{[2]}$$

Supposing trait q is the fat, protein or volume lactation yield, or the liveweight of the cow, the relative economic value requires enumeration of the derivatives of milk revenue, beef revenue and intake, for the given trait. Therefore from [2], the calculated economic value is the marginal return for a unit change in the trait, less the marginal feed costs (i.e. the cost of that feed required to produce an extra unit of that component). This is a common-sense answer. Costs per cow, costs per ha, and stocking rates have no influence on these economic values.

Average lactation yields do not influence the economic values, but average liveweight will have a slight influence on the liveweight economic value as the derivative of intake with respect to liveweight is obtained from metabolic liveweight, a function of average liveweight.

*Scenario 2.* In this alternative the stocking rate is marginally changed in order to exactly account for the change in feed demands (i.e. $\boldsymbol{x}$=0). Now the profit function (per ha) becomes

$$\boldsymbol{\pi} = \mathbf{(M+B-C)}\times\mathbf{F/I - H}$$

which on differentiating with respect to trait q gives

$$\partial\pi/\partial q = \mathbf{[F/I]}\times\partial\mathbf{(M+B-C)}/\partial q + \mathbf{[(M+B-C)/I]}\times\partial\mathbf{F}/\partial q - \mathbf{[(M+B-C)}\times\mathbf{F/[I^2]]}\times\partial\mathbf{I}/\partial q$$

Now **F** is fixed, therefore $\partial\mathbf{F}/\partial q = 0$. As before, substituting an expression for the average revenue **A=(M+B-C)/I** and for stocking rate **R=F/I** gives,

$$\partial\pi/\partial q = \mathbf{R}\times\partial\mathbf{(M+B-C)}/\partial q - \mathbf{R}\times\mathbf{A}\times\partial\mathbf{I}/\partial q$$

Dividing this expression by **R** to express the economic values on a per cow basis gives

$$\partial\pi`/\partial q = \partial\mathbf{(M+B)}/\partial q - \mathbf{A}\times\partial\mathbf{I}/\partial q \qquad \textbf{[3]}$$

Clearly, expression [3] is identical to expression [2] except the average revenue (**A**) is used in the place of purchased feed costs (**P**). Accordingly, the two models will give identical economic values if it is assumed that purchased feed is obtained at opportunity cost defined as average revenue in the base situation.

If purchased feed cost is cheaper than average revenue, this may indicate a management opportunity is not being exploited. This will depend upon the relationship between the average and marginal revenue of the production system. The purchase of additional feed would be profitable provided the marginal revenue resulting from additional feed exceeds marginal costs.

The average revenue in [3] is milk revenue plus beef revenue less cow costs, expressed per unit DM consumed. It is therefore apparent that economic weights will be sensitive to production and economic circumstances, including average lactation yields. The resulting aggregate economic index for dairy cattle when milk revenue is determined by the yields of fat, protein and volume will therefore have the form:

$$\$\text{Index} = [\partial\mathbf{M}/\partial\text{fat} - \mathbf{P}\times\partial\mathbf{I}/\partial\text{fat}] \times \text{EBV}_{\text{fat}} + [\partial\mathbf{M}/\partial\text{protein} - \mathbf{P}\times\partial\mathbf{I}/\partial\text{protein}] \times\text{EBV}_{\text{protein}} + [\partial\mathbf{M}/\partial\text{volume} - \mathbf{P}\times\partial\mathbf{I}/\partial\text{volume}]\times\text{EBV}_{\text{volume}} + [\partial\mathbf{B}/\partial\text{livewt} - \mathbf{P}\times\partial\mathbf{I}/\partial\text{livewt}]\times\text{EBV}_{\text{livewt}} \quad [4]$$

## AN EXPLICIT ECONOMIC VALUE FOR FEED

A natural rearrangement of [4] is to accumulate the intake coefficients

$$\$\text{Index} = \partial\mathbf{M}/\partial\text{fat} \times \text{EBV}_{\text{fat}} + \partial\mathbf{M}/\partial\text{protein} \times\text{EBV}_{\text{protein}} + \partial\mathbf{M}/\partial\text{volume}\times\text{EBV}_{\text{volume}} + \partial\mathbf{B}/\partial\text{livewt}\times\text{EBV}_{\text{livewt}} - \mathbf{P}\times[0\partial\mathbf{I}/\partial\text{fat}\times\text{EBV}_{\text{fat}} + \partial\mathbf{I}/\partial\text{protein}\times\text{EBV}_{\text{protein}} + \partial\mathbf{I}/\partial\text{volume}\times\text{EBV}_{\text{volume}} + \partial\mathbf{I}/\partial\text{livewt} \times\text{EBV}_{\text{livewt}}] \quad [5]$$

Equation [5] uses marginal revenues for the productive traits as their economic values (ignoring the marginal feed costs). The last term in [5] is the impact of production changes on intake, multiplied by the price of feed. This equivalent economic model can be thought of as including an explicit EBV for feed, calculated as a linear function of the changes in productive traits. The corresponding economic value for this trait is simply the feed cost. A similar expression would have been obtained if feed intake measurements were available, except that (co)variance components would have been used to obtain an EBV for feed intake. In a sense, [5] assumes perfect genetic correlation between feed intake and the production traits in the objective.

The use of the five-trait index [5] rather than the four-trait index [4] will result in identical response to selection, but has two major advantages. First, it is future proofed in that the discovery of measurements that enable prediction of feed intake will be able to be introduced at any point in the future without the need for reparameterising the index. Second, the economic values for the production traits will more closely align with the payment values, leading to more ready industry acceptance of the index than is the case when for example in New Zealand circumstances, volume and liveweight have negative economic values.

## REFERENCES

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