Economic Principles in Nutritional Monitoring

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Introduction

The dairy farm operation is very similar to other production systems in that fixed and variable inputs are used in a process that produces products. There is probably no aspect of a dairy enterprise that has wider impact than the feeding program. Dairy feeding programs have direct effects on production and growth and set the stage for future productive potential. Feed costs on the average dairy in the United States account for more than 60% of total operating expenses (USDA, 1988). Furthermore, small changes in feeding programs may bring about large changes in productivity, health, income, feed costs, labor allocation, and debt load. Without considering improved production or health effects, one study has shown that routine nutritional consultation can save 14% of total feed costs on dairies (Ferguson et al., 1987). An experimental study done on herds exposed to nutritional services showed a similar figure of 12% (Galligan et al., 1990).

Over the years a number of nutritional monitoring tools have been suggested to help management in decision making. Monitoring measures such as feed cost/cow, feed cost/cwt of milk produced, and % feed cost of milk value have been used to form the basis of many management decisions. Analytical methods to help select feed ingredients and products for use in the dairy operation have also been presented as a way to improve efficiency by controlling cost and by identifying good economic opportunities. The underlying economic principles of these monitoring measures and analytical approaches will be discussed.

## Economic Based Monitoring Measures

To understand the strengths and weaknesses of common measures used to assess the economic efficiency of a nutritional program, basic concepts of a production function must be understood (Figure 1 – a schematic production function; Dijkhuizen and Morris, 1997). A production function consists of inputs (feed, labor, capital, etc.) used in a process to produce an output (milk, calves, cull cows, etc.). Inputs can be divided into two broad but important categories, fixed or variable. A fixed input is any input that will not change over the anticipated planning horizon (size of the dairy, size of the parlor, repair cost to the mixer wagon, etc.), while variable costs are those that will change as a consequence of the decision or production level (feed cost). In Figure 1, the fixed cost is a horizontal line signifying how it is constant over all levels of input and output. In contrast, variable cost increases as variable input use is increased. Hence, the designation of fixed or variable depends on the planning horizon in which the decision is being made -- where in the long run, everything is variable - - even the decision to be in the dairy industry!

In response to these inputs is the output which has a certain value (milk, etc.). The shape of the response to the inputs is a reflection of the state of technology and is likely to change as new discoveries emerge (i.e. BST). In fact, changes in technology start out as variable inputs (adopt or not adopt) and they become *fixed* when they are broadly accepted as essential to the production system. The relationship of inputs to outputs can be described by 4 general functions, depending on how each additional (marginal) input affects output consecutively.

1) **Constant efficiency:** For each additional unit of input, the additional outputs produced stay the same. For example the first kilogram of feed produces .5 kg of milk and each additional kilogram of feed produces .5 kg of milk.

2) **Increasing efficiency:** In this situation, the number of output units increases as the level of input increases. First kilogram of feed results in .5 kilograms of milk and the second kilogram of feed results in .6 kilograms of milk.

Figure 1: A production function defining the relation between inputs and outputs.

Production Function
Where to operate?

Dollars

Feed, labor, capital ….
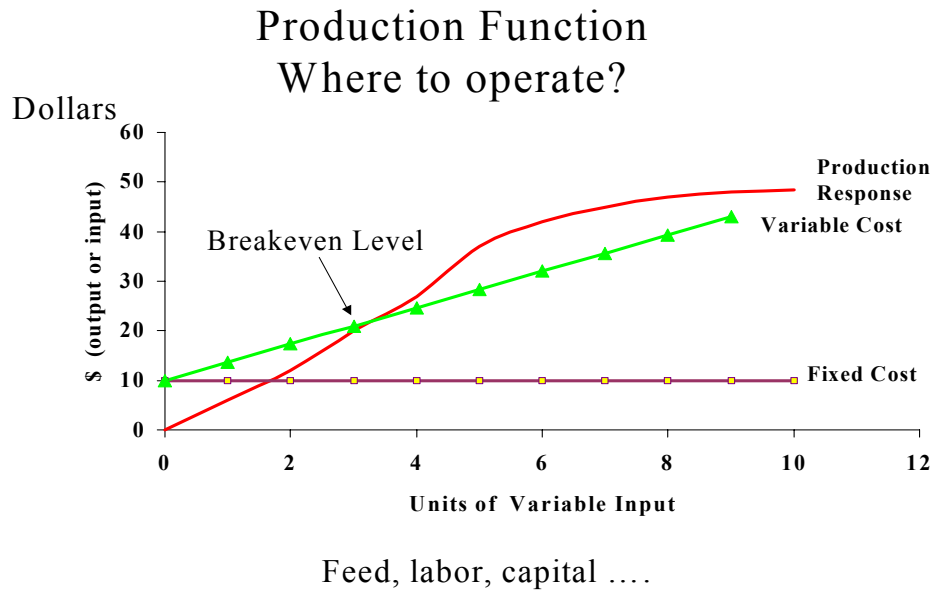
3) **Diminishing efficiency:** Each additional unit of input realizes a *smaller additional* output than the previous marginal input. The response of going from 3-4 kilograms of feed might be .8 kg of milk, while the response of going from 4 to 5 kilograms of feed is .6 kilogram of milk. So the output response is still increasing but at a diminishing level.

4) **Decreasing efficiency**: Each additional unit of input decreases the output.

A given production function might consist of all 4 of these characteristics or a subset. Most production functions have a diminishing component to them and it is within this area that often the highest profitable production point is realized. Furthermore, these relationships can be described in terms of physical units (kilograms of feed, kilograms of milk) or in economic terms (value of feed, value of milk). One can see that in the application to nutrition, the fixed cost input is daily cow maintenance cost. This cost is paid irrespective of the cow's production level. Feed fed for production is a variable input and is related to production.

Where to operate?

The issue facing the decision maker is where to operate on the production curve that maximizes
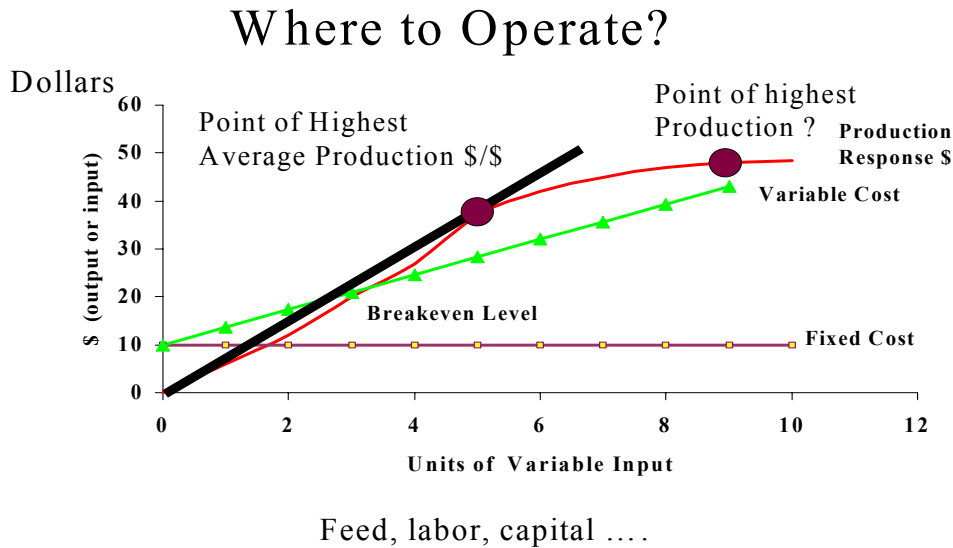
profits (returns above feed cost). Several points emerge that form the basis of economic nutritional monitoring measures often used in the field for decision making. Each will be discussed below (Figures 1,2,3).

Breakeven Level: This is the level of input needed so that the total fixed and variable cost of the inputs is equal in value to the output. One has to be above this level to cover the fixed maintenance cost of the cow as well as any variable cost associated with production (around 12-15 lbs of milk depending on milk price and feed costs). Certainly higher income over feed cost is realized at higher production levels (Figure 1).

Point of highest average production/value of feed input: This is the point where the amount of product/unit of total input cost is greatest. On the production curve it is the slope of the line that goes through the origin and is tangent to the value of the production surface. The reciprocal of this measure (feed cost/cwt of milk) is a common measure used to assess productivity, however it does not define the point of optimal production (Figure 2).

Point of highest production: The highest production level is also not associated with the highest level of profit (Figure 2).

68

Figure 2: Point of operation.

Where to Operate?

Dollars

Point of Highest
Average Production $/$

Point of highest
Production ?

**Production
Response $**

Variable Cost

Breakeven Level

Fixed Cost

$ (output or input)

60
50
40
30
20
10
0

0   2   4   6   8   10   12

Units of Variable Input

Feed, labor, capital ….

Point of optimal production: For any production system, the point of optimal production is where the marginal cost (i.e. the slope of the variable cost) is equal to the marginal value of milk production (slope of the line tangential to the production surface (Figure 3). There are many lessons to learn from this simple model. First fixed costs are not important in tactical decision making – for they do not influence the slope of the variable or total cost curve (fixed + variable costs). Furthermore, we see the point where the production/unit of input is maximal (highest average production/unit of feed) is not the point of highest profit. Hence reciprocal measures (feed cost/cwt of milk) will be similarly flawed.

As long as the value of the response (marginal milk production) is greater than the

change in feed cost (marginal feed cost) one should increase production. It is important to realize that before, as well as after the point of optimality, the producer still makes a profit – just not as high as it would be if he was operating at the optimal level.

Example application of principles: Table 1 contains the components of a production curve, where the input is ration cost and the output is milk production. We see that the feed cost/cwt measure would suggest that the 80 lb level of production is superior to the 90 lb level. However, on a marginal basis, the change in ration cost over the two production levels is $1.00 ($4-$3) while the change in marginal milk value is $1.25 ((90-80)*.125/lb). Since the marginal revenue ($1.25) is greater than the marginal cost ($1.00), a higher profit will be realized at the higher level of production.

The problem with measures such as average feed cost per hundred-weight of milk is that they include the fixed cost components (i.e. maintenance cost of the cow), thus cannot be used for tactical decision making (Should I increase my milk production level?). Decisions to control feed cost must be cautiously evaluated when using this measure.

What can be seen from the above example is the critical role that marginal cost of production

Table 1: Components of a production curve.

Milk Level	Feed Cost	Feed Cost/CWT
80	$3.00	$3 / 80 x 100 = $3.75
90	$4.00	$4 / 90 x 100 = $4.44
Milk is valued at $12.50		
What level of production is best?		

Figure 3: Optimal Point of Operation.

A Production System

Dollars

Feed, labor, capital ….
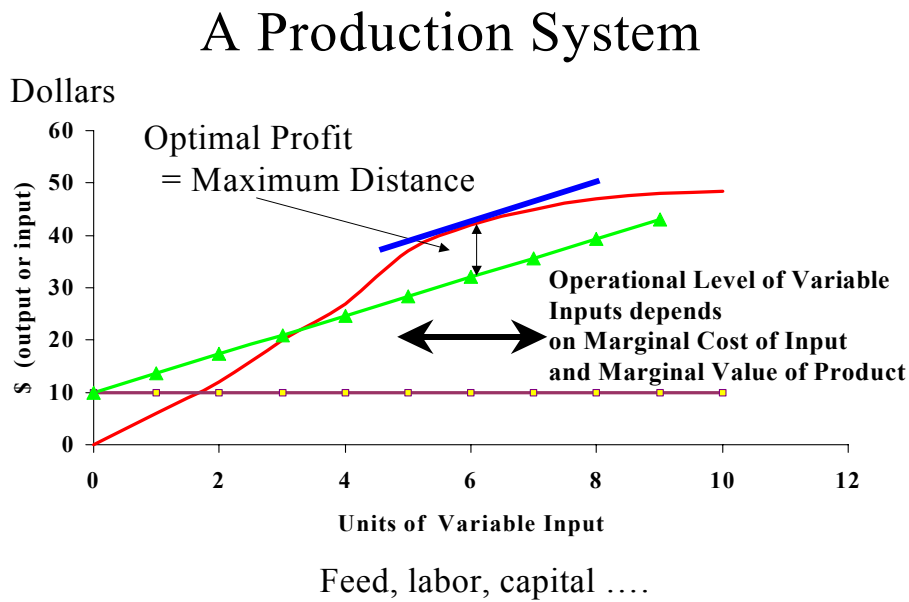
plays. One has to be careful in calculating the marginal cost of production from the field in that rations in early lactation often include feed nutrients used for weight gain (inflating cost), while ration cost at higher levels of production do not include nutrient cost for weight loss (decreasing cost estimates) – when either or both of these biases are present, marginal feed cost will be underestimated. Current estimates are typically around $ 2.50/cwt to $3.00/cwt.

Cost Efficiency

Feed Selection

Another way to improve profitability is to control cost without losing production. Cost efficiency involves using the best source of an input – irrespective of whether that input is fixed or variable. To capture cost efficiency feed must be efficiently purchased. To help in this effort, several methods have emerged over the years. The Petersen (1932) method is perhaps the most historical (Dijkhuizen and Morris, 1997). This method involves selecting two base feeds (often soybean meal and corn) to estimate the economic value of two nutrients - often energy and protein. These estimates are then used to calculate a substitution value for other feed ingredients by

multiplying the economic estimates by the nutrient content of the feed ingredient of interest.

Regression methods have also been proposed so that additional nutrients can be considered as well as additional base feeds (the market) in estimating the economic coefficients of various nutrients (St- Pierre and Glamocic, 2000). A more complete understanding of the value of a feed ingredient can be determined from linear programming packages where nutritional and non-nutritional constraints (set levels of feed ingredients) are used to estimate the marginal value of feed ingredients (Galligan et al., 1989). Furthermore, these approaches take into account the value of nutrient density as well as nutrient profiles in estimating these marginal values. Multi-period ration formulation can be used to look at how home-grown feeds (forages) should be used strategically over the year to capture price trends in purchased feed ingredients (Galligan et al., 1989).

Type I and Type II Error Analysis

Producers are constantly faced with the decision of selecting products where the production response is variable. Nevertheless a decision must be made and in fact will be made either intentionally or unintentionally (Galligan, 1991).

Figure 4: Partial budget and frequency distribution for sodium bicarbonate.

Partial Budget at other Response Levels
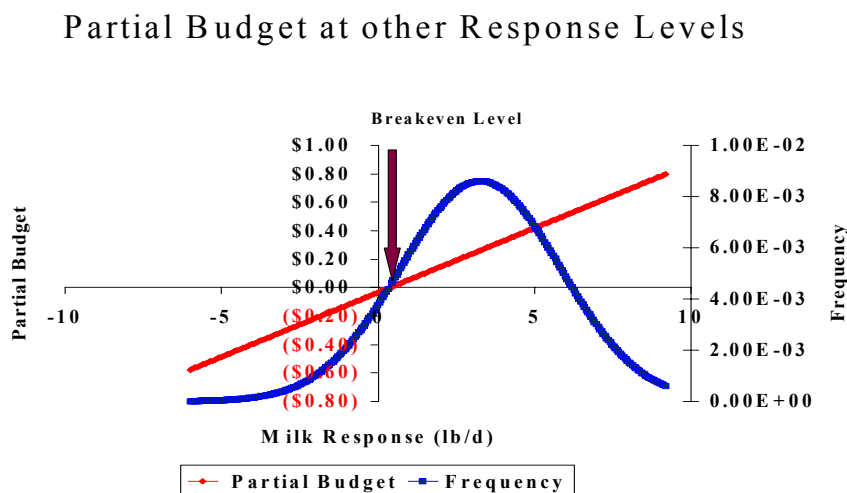
Sodium Bicarbonate

Table 2: Potential outcome of various decisions.

	Product is profitable	Product is not profitable
Use Product	Good Decision	Type 1 Error Decision
Not Use Product	Type II Error Decision	Good Decision

Table 2 outlines the possible consequence of decisions to use or not use a product. If the product is profitable (has a production response above breakeven) then failing to use the product would be a lost opportunity to the producer (type II error). If a non-profitable product is used, the producer would be committing a type I error. Type I and II error analysis involves estimating the cost of these errors – with the decision criteria being to minimize the error cost.
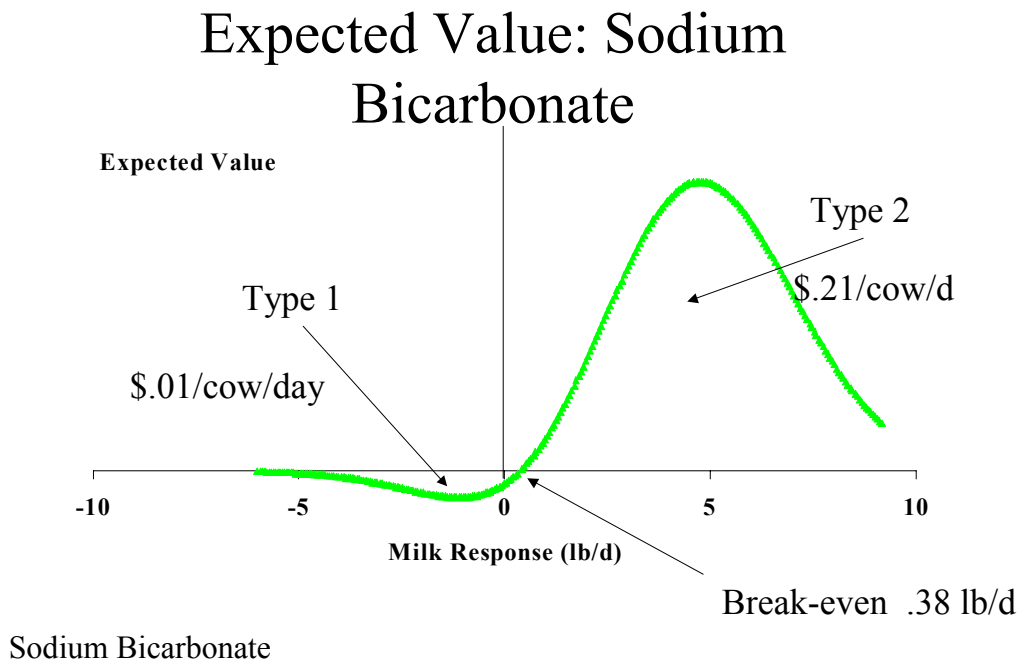
Steps in Type I and II Error Analysis

1) **Collect response data on the product.** Usually this can be tabulated from studies or summaries of studies. While many products influence several production parameters (milk yield, milk composition, reproduction, body weight gain/maintenance, etc.), it is often easier to focus on one production parameter. If the product can be justified on one production parameter and all the other effects are positive in increasing profits then the product can be used. Data collected should be the level of the response and any associated variable input (cost of the product, feed use etc.). The response across trials is used as an estimate of the risk (variation) that the producer faces in making a decision on using the product. The distribution of the response variable can be described. Typically a normal distribution is assumed and a mean response as well as its variation is calculated.

2) **Calculate a partial budget for each possible production response level.** This involves identifying the changes in revenue and changes in cost associated with each production level. From this partial budget, the breakeven level of production can be calculated by finding the level of production where the partial budget equation is zero (Figure 4).

3) **Convert the frequency distribution of responses to a histogram of small increases (.01 units) of response (Figure 4).** The frequency of response levels is multiplied by the corresponding partial budget at that response to yield an expected value (Figure 5). The expected

Figure 5: Expected value distribution for sodium bicarbonate.

Expected Value: Sodium Bicarbonate

Expected Value

Type 1

$.01/cow/day

Type 2

$.21/cow/d

-10   -5   0   5   10

Milk Response (lb/d)

Break-even .38 lb/d

Sodium Bicarbonate

values below breakeven are integrated to estimate the cost of type 1 error - using an unprofitable product. The integration of the expected values above breakeven gives the estimated type II error.

When applied to three products (BST, Megalac®, and sodium bicarbonate) the type I errors were all less than the type II errors and thus the decision should be to use the products (Figure 6). It is important to realize that type II error is a *lost opportunity,* which is sometimes difficult for producers to accept as a cost to their operation.

There are several methods to evaluate decisions where risk (variation, uncertainty) plays a role (maximin, minimax, maximax, Hurwicz, Laplace) in addition to type I and II analysis. In addition there are stochastic dominance methodologies, which can rank decisions on the degree of trade off between returns and risk.

As products become a more integral part of the dairy operation it is necessary that consultants understand methodologies to help in selecting which ones to use.

Figure 6: Type I and II application to three products.

Example of Three Products

Product	Type 1 Error	Type II Error
Sodium Bicarb	$.01	$.27
Megalac	$.15	$.60
BST	$.04	$.60

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