Derivation Of Economic Values Considering Nitrogen Loss

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Introduction

In the past two decades, nutrient losses from dairy farms have been a matter of growing concern on a global scale. In particular, nitrogen contributes to environmental pollution as ammonia in the air and as nitrate in the soil and groundwater (Tamminga (1992)). Consequently, there is growing awareness worldwide of the necessity to reduce nitrogen loss and protect the environment from nitrogen pollution. Breeding objectives have been defined within the context of economic theories. However, in future there will be need for breeding objectives that consider environmental pollution to drive breeding programs. In that case, economic values used in breeding objectives will not only depend on economic objectives (i.e., profit and economic efficiency) but also on environmental variables (i.e., nitrogen loss and nitrogen balance). This paper presents a procedure for the derivation of economic values with explicit consideration of nitrogen loss from a dairy farm.

Method

Profit. The scaling theory of Smith et al. (1985) can be applied to reduce the environmental impacts of animal production. If N is the nitrogen loss per cow per year (kg) and n is the original number of animals, the total nitogen loss after rescaling of the farm is given by:

$$Nn = (N + \Delta N)(n + \Delta n) = Nn + N\Delta n + n\Delta N + \Delta N\Delta n \qquad (1)$$

It is assumed that there is legislation restricting N on dairy farms and therefore an increase in N will reduce the number of animals in the farm. If the second order term is ignored, then:

$$\Delta n = -\Delta N / N \times n \qquad (2)$$

Consider the profit equation $P = R\text{-}C$, where R is the returns and C is costs. The total farm profit (T) before genetic change is

$$T = nP = n(R - C) \qquad (3)$$

After a small change in trait x, Δx , and rescaling the farm so that the legislation is not exceeded, the new farm profit T_1 is

$$T_1 = (n + \Delta n)[P + (\frac{\partial R}{\partial x} - \frac{\partial C}{\partial x})\Delta x] = nP + n(\frac{\partial R}{\partial x} - \frac{\partial C}{\partial x})\Delta x + P\Delta n + (\frac{\partial R}{\partial x} - \frac{\partial C}{\partial x})\Delta x\Delta n \qquad (4)$$

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Ignoring the second order term (i.e., $(\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x})\Delta x\Delta n=0$), the change in the total farm profit is given by:

$$\Delta T=T_1-T=n(\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x})\Delta x+P\Delta n=n[(\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x})\Delta x+\frac{\Delta n}{n}P] \quad (5)$$

Substituting for Δn in eq(2) gives

$$\Delta T=n[(\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x})\Delta x-\frac{\Delta N}{N}P]=n\Delta x(\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x}-\frac{P}{N}\frac{\Delta N}{\Delta x}) \quad (6)$$

The economic value under legislated situations (a_x^*) is

$$a_x^*=\frac{\Delta T/n}{\Delta x}=\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x}-\frac{P}{N}\frac{\Delta N}{\Delta x}=a_x-\frac{P}{N}\frac{\Delta N}{\Delta x} \quad (7)$$

where a_x is the ordinary unconstrained economic value (= $\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x}$) and $\Delta N/\Delta x$ is the nitrogen value which is defined as N as a result of one unit change in genetic merit of the trait.

Eco-economic efficiency. If the eco-efficiency is defined as the ratio of profit to nitrogen loss (P/N) and the breeding objective is to maximize the eco-economic efficiency, then the economic values (a_x^{**}) is

$$a_x^{**}=\frac{\partial(P/N)}{\partial x}=\frac{1}{N}\frac{\partial P}{\partial x}-\frac{P}{N^2}\frac{\partial N}{\partial x}=\frac{1}{N}(\frac{\partial P}{\partial x}-\frac{P}{N}\frac{\partial N}{\partial x})=\frac{1}{N}a_x^* \quad (8)$$

The relative economic values estimated based on eco-economic efficiency and those estimated under the legislated situations are actually equal.

Economic efficiency. Economic efficiency has sometimes been defined as the breeding objective (Dickerson (1970); Hirooka et al. (1998b)). Assuming such a situation, the economic values for economic efficiency ($Q=R/C$) can be derived as

$$\frac{\partial Q}{\partial x}=\frac{\partial(R/C)}{\partial x}=\frac{1}{C}\frac{\partial R}{\partial x}-\frac{R}{C^2}\frac{\partial C}{\partial x}=\frac{1}{C}[\frac{\partial R}{\partial x}-\frac{\partial C}{\partial x}+\frac{\partial C}{\partial x}(1-Q)]=\frac{1}{C}[\frac{\partial P}{\partial x}+\frac{\partial C}{\partial x}(1-Q)]$$

Therefore, under this scenario, then the economic value considering N (a_x^{***}) can be derived using eq.(7) as:

$$a_x^{***}=\frac{\partial Q}{\partial x}-\frac{P}{NC}\frac{\Delta N}{\Delta x}$$

Numerical example

The economic and nitrogen values of traits for dairy cattle reported by Steverink et al. (1994) were used and are shown in Table 1. In that study, nitrogen loss were from run-off, leaching, denitrification and volatilization. They were determined at farm level as the difference between nitrogen input through purchased concentrates, fertilizer and roughage and through deposition and nitrogen output through sold milk, meat, roughage and manure removed from the farm. The return and cost were given as 5678 Dfl/cow/year and 4791 Dfl/cow/year, respectively. Labor income was used instead of profit and was given as 887 Dfl/cow/year. The N was 187 kg/cow/year. The economic values estimated after considering N are also shown in Table 1. For example, the economic value of fat under the legislated situation was obtained as $4.72 = 0.78 - \frac{887}{187} \times (-0.83)$. Comparison of economic values with and without N showed that higher fat percent and lighter body weight were emphasized more under legislated situations, because higher fat production and decrease in body weight resulted in a reduction in N (Steverink et al. (1994)). The economic values for economic efficiency were not obtained in this study due to lack of $\frac{\partial C}{\partial x}$ in Steverink et al. (1994).

Table 1: Economic (a_x) and nitrogen values[a] and economic values (a_x^*) derived considering nitrogen loss

Trait	a_x	Relative a_x	Nitrogen value	a_x^*	Relative a_x^*
BW	-0.05	-0.2632	0.22	-1.0935	-7.67
Carrier	-0.19	-1	-0.01	-0.1426	-1
Protein	13.81	72.68	0.23	12.72	89.21
Fat	0.78	4.11	-0.83	4.72	33.09

[a] Cited from Steverink et al. (1994).

Discussion

It appears that genetic improvement can help reduce N per kg product through improved productivity and nitrogen use efficiency. Steverink et al. (1994) reported negative economic and nitrogen values for carrier (i.e. milk yield) which is similar to those estimated in this study when considering N. Improvement of milk yield may reduce N per kg milk but enhance N per individual.

The procedure proposed here requires nitrogen values as well as economic values. The economic values have been estimated based on economic statistics (Lindoholm and Stonaker, 1957), profit functions (Ponzoni (1986); Ponzoni and Newman (1989)) and bio-economic models (Groen (1988); Hirooka et al. (1998ab); Amer et al. (2001)). In contrast, nitrogen values were only estimated by Steverink et al. (1994) using an environmental-economic linear programming model. However, when the sub-model for predicting N is integrated in the bio-economic models, the nitrogen values can be estimated by increasing the mean of trait i (μ_i to $\mu_i + \Delta$) while keeping the mean of other traits at the current level in the integrated model as:

$$\frac{\Delta N}{\Delta x} = \frac{N_{\mu_i + \Delta x} - N_{\mu_i}}{\Delta x}$$

The nitrogen prediction models by Wilkerson et al. (1997), Kebreab et al. (2005) and Hirooka et al. (2007) can be used in this regard.

Conclusions

This study provides a procedure for derivation of economic values incorporating environmental concerns. As the procedure requires nitrogen values as well as economic values, development and use of bio-economic models with the sub-model for predicting nitrogen excretion and loss will be necessary to obtain the nitrogen values. Although the focus was on nitrogen, the procedure can apply straightforwardly to other environmental pollutants such as phosphorus and greenhouse gases. The future breeding program will need to be tailored to optimize production within nutrient use constraints.

References

Amer, P. R., Simm, G., Keane, M. G., Diskin, M.G., and Wickham, B. W. (2001) *Livest. Prod. Sci.,* 67:223-239.

Dickerson, G. E. (1970) *J. Anim. Sci.,* 30:849-859.

Groen, A. F. (1988) *Agric. Syst.,* 27:195-213.

Hirooka, H., Groen, A. F., and Hillers, J. (1998a) *Anim. Sci.,* 66:607-621.

Hirooka, H., Groen, A. F., and Hillers, J. (1998b) *Anim. Sci.,* 66:623-633.

Hirooka, H., Terada, F., and Liang, J. B. (2007*) Livest. Sci.,* 107:282-288.

Kebreab, E., France, J., Mills, J. A. N., Allison, R., and Dijkstra, J. (2002) *J. Anim. Sci.,* 80:248-259.

Lindholm, H. B., and Stonaker, H. H. (1957) *J. Anim. Sci.*, 998-1006.

Ponzoni, R. W. (1986) *J. Anim. Breed. Genet.*, 103:342-357.

Ponzoni, R. W., and Newman, S. (1989) *Anim. Prod.,* 49:35-47.

Smith, C., James, J. W., and Brascamp, E. W. (1986) *Anim. Prod.,* 43:545-551.

Steverink, M. H. A., Groen A. F., and Berentsen, P. B. M. (1994) *Livest. Prod. Sci.,* 40:251-261.

Tamminga, S. (1992) *J. Dairy Sci.,* 75:345-357.

Wilkerson, V. A., Mertens, D. R., and Casper, D. P. (1997) *J. Dairy Sci.,* 80:3193-3204.