A. F. Groen

# Cattle breeding goals and production circumstances

# Stellingen

1. In de veeteeltkundige literatuur met betrekking tot de berekening van economische waarden van genetisch bepaalde kenmerken komt onvoldoende tot uitdrukking dat 'verbetering van de genetische aanleg' een vorm van technologische ontwikkeling is.

2. De keuze van het fokdoel dient gebaseerd te zijn op de bedrijfseconomische doelstellingen en de verwachte bedrijfseconomische en maatschappelijke omstandigheden van de individuele veehouder. (dit proefschrift)

3. "Zelfs al blijken sommige prijzen, maatschappelijk gezien, misleidende aanwijzers te zijn, dan toch kan niet van de ondernemer gevergd worden deze aanwijzingen niet op te volgen." (Horring, J., 1948. Methode van kostprijsberekening. Ten Kate, Emmen)

4. De economische waarde van 'voeropnamecapaciteit' bij melkgevende dieren wordt in sterke mate bepaald door de onderlinge kostenverschillen tussen voedermiddelen. (dit proefschrift)

5. Onjuiste aannames met betrekking tot de toekomstige vorm van melkproduktiebeperking leiden tot een derving van 1 tot 6% van de opbrengsten van het fokprogramma. (dit proefschrift)

6. De toepassing van nieuwe reproduktie-technieken heeft tot gevolg dat onderzoek op het gebied van de fokwaardeschatting voor vleesproduktie-geschiktheid bij rundvee zich moet richten op de selektiemogelijkheden binnen zuivere vleesrassen. (Groen, A.F., Korver, S. and Giesen, G.W.J., 1988. In: Advances in animal breeding: proc. of the world symposium in honour of prof. R.D. Politiek)

7. Het beleid van de Landbouwuniversiteit gericht op internationalisering komt niet tot uitdrukking in de voor haar werknemers beschikbare budgetten voor buitenlandse reizen.

8. Het gebruikelijke, zeer late aanvangstijdstip van studentenfeesten is niet bevorderlijk voor een goede integratie tussen studenten en docenten.

9. Het gegeven dat landbouwhuisdieren levende wezens zijn, begaafd met gevoel en willekeurige beweging, bepaalt de speelruimte waarbinnen de ontwikkeling van nieuwe technologie in de veeteelt dient plaats te vinden.

10. 'Europa 1992' is niet grenzenloos.

11. De milieuproblematiek maakt duidelijk dat de automobiel niet zichzelf voortbeweegt.

A.F. Groen
Cattle breeding goals and production circumstances
Wageningen, 7 april 1989

# Cattle breeding goals and production circumstances

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# Cattle breeding goals and production circumstances

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*aan mijn ouders,*

*aan Rita*

## Voorwoord

Het aan dit proefschrift ten grondslag liggende onderzoek is uitgevoerd gedurende mijn aanstelling als promotie-assistent bij de vakgroepen Agrarische Bedrijfseconomie en Veefokkerij van de Landbouwuniversiteit te Wageningen.

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## Contents

## Introduction

Definition of the breeding goal is an important aspect of animal breeding. The general goal of animal breeding is: obtaining a new generation of animals that will produce the desired products more efficiently under future farm economic and social circumstances than the present generation of animals (Politiek, 1962). In defining breeding goals, relative emphasis has to be put on animal traits in selecting males and females which will become parents of the next generation of animals. Hazel (1943) provided a basis for application of selection indexes in defining goals in animal breeding. Hazel (1943) denoted, that an index constructed from data of one enterprise may not be widely applicable. Considered parameters in constructing selection indexes (economic values and standard deviations of traits) may vary with the particular locality or nature of the enterprise, or with different managerial practices.

In 1985, a working group of the Dutch National Council of Agricultural Research concluded that the then used methods to define breeding goals might fail to include adequately the influences of economic and social circumstances of animal production (Van der Werf, 1985). The working group appealed for further research on the derivation of the economic value of improvement of genetic merit, considering:

- the methodology to use in deriving economic values, including choice of an interest of selection and a planning term;
- an extension of the then commmonly considered traits (milk production traits) with other groups of traits (beef production traits, feed intake capacity, susceptibility diseases);
- a quantification of the extent to which production circumstances influence the economic values of improvement of genetic merit.

In 1986, a research project was started in order to study the above-mentioned issues. This thesis describes the results of that project, on the relationship between "cattle breeding goals and production circumstances".

Chapter one deals with the general aspects of the problem: aims and method of the project are elucidated from a general reflection on the relationship between breeding goal and production circumstances and a discussion on the definition of efficiency of production and derivation of economic values.

Chapter two describes the dairy farm model used to derive economic values of milk and beef production traits and feed intake capacity.

Chapter three and four give the results on the sensitivity of economic values of milk and beef production traits in situations without and with limitations, respectively.

Chapter five deals with the sensitivity of the economic value of feed intake capacity. Special attention is paid to the method to derive the economic value of feed intake capacity.

The study on the sensitivity of economic values towards production circumstances provided more detail information on the concepts when deriving economic values. Theoretical concepts of economic production theory for different perspectives in deriving economic values are compared in chapter six.

Chapter seven deals with the carrying-over-effects of the sensitivity of economic values on revenues of cattle breeding programmes. Results indicate to what extent incorrect predictions on production circumstances when defining breeding goals will lead to losses in economic revenues of breeding programmes.

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Chapter one

# Cattle breeding goals and production circumstances. General Aspects.

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## ABSTRACT

This chapter is an introduction to the research project on the relationship between cattle breeding goals and production circumstances. In the **INTRODUCTION**, the terms 'breeding goal' and 'production circumstances' are elucidated. A general reflection on the relationship between breeding goals and production circumstances and the importance of this relationship are given. In order to support elaboration of aims and method of this research project, two items are elucidated: 1. definition of **EFFICIENCY OF PRODUCTION** in defining breeding goals and 2. **DERIVATION OF ECONOMIC VALUES**. Thereupon, aims and method of this research project on definition of cattle breeding goals in relation to production circumstances are elaborated.

## 1. INTRODUCTION

The general goal of animal breeding is: obtaining a new generation of animals that will produce the desired products more efficiently under future farm economic and social circumstances than the present generation of animals (Politiek, 1962). In selecting females and males that will be used as parents of the next generation, a major problem is the relative emphasis which is to be put on animal traits which influence the efficiency of production. Selection indexes (Hazel, 1943) provide possibilities for the definition of a concrete breeding goal (in terms of an aggregate genotype selected for by a correlated information index) that can be used directly in selecting parents. Genetic gain for the aggregate genotype is optimized by maximizing the correlation between aggregate genotype and index. Which traits should be included in the aggregate genotype and index and the relative emphasis these traits will obtain, depends upon three aspects (Harris, 1970):

1. relative contribution of improvement of the trait to improvement of efficiency of production;
2. potential for genetic improvement of the trait (e.g. genetic variability);
3. costs of accurate estimation of genetic merit of animals for the trait (in labour, facilities and time).

The term 'production circumstances' is used to denote the total or part of the total circumstances that determine the organisation and the efficiency of production. In order to give an idea of the diversity of production circumstances, two classifications are given. A general classification is:

- natural circumstances: e.g. climate, type of soil;
- social circumstances: e.g. educational levels, traditions, statutary regulations;
- economic circumstances: e.g. market type, governmental policies, technological developments, price ratios.

A classification of circumstances of animal production farms possibly influencing the definition of the breeding goal was given by Smith (1986):

- production system (e.g. feeding system);
- market requirements (payment system and differentials for quality);
- breeding stock (e.g. average production level);
- improvement system (breeding organisation);
- uncertainty.

The relationship between breeding goal and production circumstances arises from the influences of production circumstances on the three aspects mentioned that determine the relative emphasis of animal traits within the (concrete) breeding goal. Relative economic values for a trait may vary with the particular locality or nature of the enterprise (Hazel, 1943). Published research results indicate, that product prices are likely to influence relative contributions of the improvement of animal traits to (economic) efficiency of production (e.g. Adelhelm et al., 1972). Different managerial practices may cause the standard deviations for traits to vary in different herds (Hazel, 1943). For example; average milk production levels influence levels of genetic and phenotypic variances (Mayala and Hanna, 1974).

Knowledge on the relationship between breeding goal and production circumstances is of importance for:

1. an accurate definition of the breeding goal, giving optimum levels of economic revenues of the breeding programme, according to the future state of production circumstances;
2. an accurate calculation of the level of economic revenues of breeding programmes, in order to optimize the structure of the programme.

The importance of this knowledge is stressed by the character of future production circumstances: they are not known without error, they are not constant in time, and they differ between countries, regions or farms. Therefore, the extent to which changes in production circumstances influence breeding goals is to be determined. First, this knowledge can help to concentrate on the 'important' circumstances in predicting the future. Secondly, when gradually or suddenly the picture of future states of the important circumstances changes, one will be able to determine to what extent breeding goals have to change. Thirdly, when different states of the important circumstances are expected or when there is much uncertainty, one will have to decide on diversification of breeding goals (as discussed by Smith (1985; 1986)).

## 2. EFFICIENCY OF PRODUCTION

One of the three mentioned aspects that influence the relative weight of animal traits in defining the concrete breeding goal is the relative contribution of the improvement of the trait to improvement of efficiency of production. What is considered to be the efficiency of production? Efficiency of production is a function of inputs and outputs of the production system. Inputs can be defined as the total of production-factors required for production within the system; outputs as the total of products resulting from production within the system. In defining efficiency, three options, corresponding with three questions, can be distinguished:

1. Are inputs and outputs, and hence efficiency, defined in biological or in economic terms?
2. How to weigh inputs and outputs within the efficiency function?
3. At which level to define the production system? and at what size?

### 2.1. Biological versus economic definition

In calculating inputs and outputs of a production system, two aspects are of importance:

1. the amounts of each production-factor required and product produced;
2. the values per unit of production-factor and per unit of product.

Differences between biological and economic efficiency are restricted to differences in the way of defining inputs and outputs. In the biological definition, inputs and outputs are expressed in energy and/or protein terms (e.g. Aleandri et al., 1984); in the economic definition this is done in terms of money. The major problem arising with the biological definition is that not all inputs and outputs can be expressed in terms of energy and/or protein. The economic definition largely deals with this problem. A disadvantage of the economic expression is weakness in stability in time and place of monetary units (Schlote, 1977). Notwithstanding imperfectness, money is "the standard for measuring value" (Stonier and Hague, 1964). Therefore, efficiency of production is considered to be economic efficiency, and the contribution of improvement of a trait to improvement of efficiency is called 'economic value'.

## 2.2. Efficiency function

Three possibilities to define the efficiency function of the production system are (Harris, 1970);

- maximize profit (= outputs - inputs);
- minimize costs per unit of product;
- maximize revenues/costs.

It was argued convincibly by Harris (1970), that in defining breeding goals, definition of efficiency function has to correspond to the individual livestock producer's interest of selection. Breeding organisations should be concerned with the individual producer's interest, because the producer's primary reason to buy a certain breeding stock at a certain price, will be based upon his assessment of how animals will contribute to the efficiency of his firm (Harris, 1970). As the individual agricultural producer deals with a competitive market (no individual price setting), his interest will be profit maximization rather than cost price minimization (Stonier and Hague, 1964). According to Pearson (1986), in temperate zones breeding goals for intensive milk production have been developed for producers or groups of producers rather than for taxpayer-financed national programs and therefore, emphasis is put on profit maximization. National governmental interest might be cost price minimization. When breeding goals are focused on the individual producer's interest, surely a result will be reduced cost prices. Possibly the rate of cost price reduction will be higher when breeding goals are focused directly on cost price reduction. Note the possibilities of governements to impose their interests to individual producers by creating social and economic production circumstances (Schieffer, 1979).

James (1982) pointed out, that the choice of a definition of effeciency may affect levels of economic values given to different traits. If fixed costs are included, economic values obtained when applying a profit definition will be influenced by the relative size of fixed and variable costs, but those obtained when applying a cost price or a revenues/costs definition will not be influenced. Brascamp et al. (1985) argued that economic values should be calculated while assuming a 'normal profit equilibrium' market situation. Application of normal profit assumptions (among others, all costs are variable costs and purely competitive markets) leads to equivalence of economic values obtained when applying each of the three efficiency functions. General applicability of the normal profit assumptions is not clearly determined; given nowadays governmental price policies, the existence of purely competitive markets in agricultural industries is doubtful.

In literature, choice of an efficiency function is not only related to the decision-maker aspect (as discussed above) but also to the questions 'who benefits from improved efficiency?' and 'what limits production size?' (Miller and Pearson, 1979). However, answers to these questions determine definition of the production system rather than definition of efficiency function in deriving economic values.

## 2.3. Definition of the production system

Definition of the production system in deriving economic values includes definition of level and size of the system. In the following part, a system is considered to be a finite number of elements, together with relationships between elements and their environment (Gal, 1982). A sub-system is a non-empty part of a system. The behaviour of a system is the way in which it reacts to endogeneous or exogeneous impulses.

The animal production system has a hierarchically levelled structure, as shown in figure 1. Given a system level, systems at lower levels are considered to be sub-systems, whereas relevant elements of systems at higher levels are the environment. Difference is made between aggregation of same and different sub-systems (at a certain level) to the next level. Example given: going from animal to herd level, same systems (in terms of same elements which may differ in state of the elements: different ages or production level) are aggregated; going from herd to farm level other sub-systems such as feed production and buildings may be included. At the farm level, an additional differentiation of levels may occur. A common differentation in animal production is nucleus breeder -- multiplier -- fattener. At the sector level, differentiation of the production column may also be further carried through.

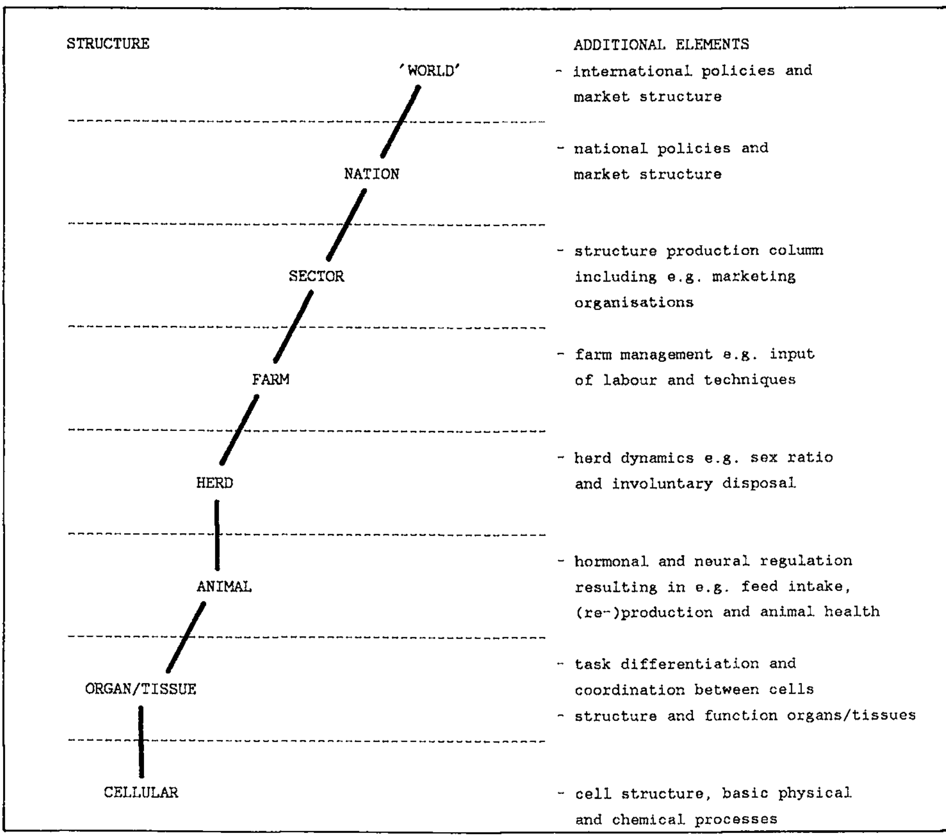


*Figure 1: The hierarchical structure of the animal production system.*

Genetic merit is tied up to the level of an individual animal, not just an organ or tissue. Therefore, the animal level is the lowest level considered in deriving economic values.

Improvement of genetic merit of animals increases efficiency of production. Long run effects of greater efficiency will be lower market prices (Cochrane, 1958). Yet, a cyclic interaction can be observed. Economic values (and hence level of improvement of traits) are influenced by product and production-factor prices (see 1. and 2.1), and level of improvement of a trait will itself influence future prices. Therefore, derivation of economic values ideally requires knowledge of the future levels of improvement of genetic merit and their price effects (Niebel, 1986). The theoretically appropriate level to be used in deriving economic values in animal breeding is the one for which limited resources and prices of products and production-factors are influenced by an improvement of a trait (Fewson, 1982).

Although theoretically appropriate, national or international levels or sector level are rarely chosen because of methodological problems (magnitude of the system). Most calculations of economic values are restricted to the animal, herd or farm level.

Beside definition of level of the system, size of the system needs to be defined in deriving economic values. Three different bases of evaluation in defining size of the production system can be distinguished:

- fixed number of animals within the system;
- fixed input of a certain production-factor;
- fixed output of a certain product.

Considering the animal level in deriving economic values, implicitly the first base of evaluation is assumed. On higher levels, all three bases are possible. Considering farm level, the second and third base can be interpreted in terms of limited availability of e.g. feed and restrictions on e.g. milk output, respectively. Apparently, choice of a base of evaluation is determined by production circumstances.

Smith et al. (1986) argued that it would be better to apply two conditions in deriving economic values: regard all fixed costs as variable costs per unit product and assume a fixed output (rescaling). According to Smith et al. (1986), derivation of economic values is restricted to calculation of changes in cost price per unit product when applying these conditions.

Additional benefits of taking away current inefficiencies are disregarded. Smith et al. (1986) showed equivalence of economic values when the first condition was applied either with rescaling on base of fixed output, fixed input or fixed profit. Van Arendonk et al. (1985) and Zeddies (1985) denoted substantial influence of the introduction of milk quota system (change from fixed number base to fixed output base) on the economic values of milk production traits.

## 3. DERIVATION OF ECONOMIC VALUES

Beside the direct contribution of improvement of a trait to improvement of efficiency (economic value), the aspects of time and frequency of expression of improvement (cumulative discounted expression; Brascamp, 1973; McClintock and Cunningham, 1974; Danell, 1980) are of importance in defining breeding goals and calculation of returns of breeding programs. This aspect can be included in deriving economic values (to obtain so called discounted economic values). Calculation of cumulative discounted expressions is not discussed in this chapter.

### 3.1. Principles and conditions

The economic value of a trait expresses the contribution of a genetic improvement of a trait to the improvement of economic efficiency of the production system. Assuming, that efficiency is a function of inputs and outputs of the system (paragraph 2.) and, that inputs and outputs have an amount-aspect and a value-per-unit-aspect (paragraph 2.1), derivation of economic values concerns:

1. quantification of the changes in physical amounts of inputs and outputs of the system as a result of a change in genetic merit;
2. valuation of these changes in physical amounts.

Conditions for methods to derive economic values result from:

- their application in the aggregate genotype;
- the choice of an efficiency function, level and base of evaluation of the

system;

- influences of production circumstances.

Economic values are applied in defining concrete breeding goals (selection index theory). As (genotypic and phenotypic) correlations between traits are considered in maximizing the correlation between aggregate genotype and information index (Hazel, 1943), the economic value of a trait has to be derived by changing genetic merit of the trait allowing no simultaneous change in genetic merit of other traits.

New generations of animals will produce under future production circumstances. Therefore, a method will have to allow for the use of future product and production-factor prices.

If conditions result from the choice of an efficiency function, level and size of the production system are self-evident. The method has to result from the choices made.

Literature shows evidence, that economic values are influenced by production circumstances (e.g. Adelhelm et al., 1972; Van Arendonk et al., 1985). Influences of managerial practices may ask for the definition of 'standard' circumstances at which economic values have to be derived (Elsen et al., 1986). Optimization of farm management is a major tool to achieve high efficiency of the production system. Therefore, optimum management might be chosen as standard. This would impose the condition, that it must be possible within the model to define management at which efficiency is at maximum.

## 3.2. Methods

Surveys on methods used in derivation of economic values are given by e.g. Schlote (1977), Elsen et al. (1986) and Niebel (1986). In this paragraph, emphasis is put on the extent to which each method meets conditions stated in 3.1. (including suitability of each method for use with different efficiency functions, levels and sizes of the production system).

Two types of methods are distinguished: non-objective and objective. Non-objective methods, as opposed to objective methods, do not derive economic values by direct calculation of influences of improvement of a trait on the increase in efficiency of the system. Two non-objective methods are distinguished:

- subjective: Subjective assignment of economic values is used only for traits for which it is difficult to perform an objective calculation (e.g. udder or other body scores). Fewson (1976) proposes to relate economic values of such traits to a fixed percentage of economic values of the most important aggregate genotype traits. Nordskog (1986) proposes a simplified approach to assign economic values. He distinguishes primary and secondary traits, and proposes to calculate economic values for primary traits only and to assign zero values to secondary traits. The latter have only value through their correlations with primary traits. This approach may be suitable on animal level, but not on herd level. Correlations between traits do not reflect influences of secondary traits (e.g. involuntary disposal) on herd dynamics.
- desired or restricted gain: These methods assign economic values in order to achieve a desired or restricted amount of genetic gain for each trait (Niebel and Van Vleck, 1983; Brascamp, 1984). As pointed out by Schultz (1986) these methods may be useful in commercial pig and poultry breeding because commercial breeders tend to calculate economic values according to the performance of their stock relative to those of other breeders (see also De Vries, 1988).

Possibilities of application of non-objective methods are numerous. However, application is questionable and has to be restricted to situations and/or traits where no objective method is applicable.

The principal tool used in objective methods to derive economic values is a model. A model is an equation or a set of equations that represents the behaviour of a system (France and Thornley, 1984). Modelling is also refered to as 'systems analysis'. The aim of systems analysis is to study real-life systems by means of artificial systems (Gal, 1982). Systems analysis concerns both building and analysis of models. Cartwright (1979) described steps involved in applying systems analysis. Two approaches of systems analysis can be distinguished: positive approach or data evaluation and normative approach or data simulation (James and Ellis, 1979).

- data evaluation: Combination of economic results and technical data of farms can be used to derive economic importance of animal traits (e.g. Andrus and McGilliard, 1975; Dijkhuizen, 1983). Data evaluation is used only at animal, herd or farm level. Economic data evaluation uses current prices, which makes the method less suitable in deriving economic values.

- data simulation: A single-equation simulation model is generally called a profit equation. A number of examples on profit equations is given by Miller and Pearson (1979). Regarding the strict definition of profit in paragraph 2.2., the term 'efficiency equation' better represents these types of modelling. Tess et al. (1983) used the term 'bio-economic model' for a multi-equation simulation model to study effects of genetic changes in pork production on efficiency of production. Using efficiency equations, economic values can be derived by either partial differentation of the equation or by studying influences of a marginal unit of change in genetic merit on efficiency. Extension to multi-equation models restricts derivation of economic values to the latter possibility. In general, using simulation models, economic values are derived by studying the behaviour of the system as a reaction to changes of levels of the (endogeneous) elements that represent genetic merit of the animals. Possibilities of applying different prices and efficiency functions, levels and sizes of the production system are numerous. Number of elements to be taken into account is limited when using efficiency equations. Bio-economic modelling offers better opportunities to consider large numbers of elements and their relationships. Thereby, only bio-economic modelling allows for the implementation of mathematical programming techniques to optimize production systems. Henze et al. (1980) describe a regional equilibrium linear programming model to calculate economic values. This model includes the agricultural sector of a region, with partitioning of different groups of farms with different production possibilities. Ladd and Gibson (1978) point to the possibilities of sensitivity analysis as a direct method to obtain economic values when using linear programming.

## 4. DISCUSSION

Principles of the relation between definition of breeding goals and production circumstances are given and the importance of studying this relation is discussed. In defining cattle breeding goals, a lot of information is lacking on the relation between production circumstances and the economic values of different animal traits. Following up the work of Adelhelm <u>et al.</u> (1972), Van Arendonk <u>et al.</u> (1985) and Zeddies (1985), research may be focused on the influences of production circumstances on economic values. A study on the influences of production circumstances might best be carried out by applying systems analysis, using bio-economic modelling of a dairy farm. Bio-economic modelling is thought to give good possibilities of studying different traits and influences of different production circumstances. Modelling at farm level will give a good insight into the sensitivity of economic values towards circumstances that determine the organisation and efficiency of production at animal, herd, farm and sector level. Such a study will have to be complemented by a study on the carrying-over-effects of the sensitivity of economic values on the revenues of breeding programmes.

Within a study on the sensitivity of economic values, it is important to work on a theoretical substantiation of the way to derive economic values in animal breeding. Therein, it will have to be denoted in what way and to what extent, choice of interest of selection (definition of the efficiency function) and base of evaluation (size of the system) determine quantification and valuation of changes in inputs and outputs. In deriving economic values, valuation of changes in inputs and outputs has to correspond to the individual producer's interest and production circumstances. It has to be studied whether or not application of the conditions proposed by Smith <u>et al.</u> (1986) results in a proper valuation of changes in inputs and outputs. An important aspect of a theoretical substantiation is applicability of the normal profit assumptions as given by Brascamp <u>et al.</u> (1985).

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Chapter two

# Derivation of economic values in cattle breeding. A model at farm level.

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ABSTRACT

A deterministic static model for calculation of economic values in cattle breeding is developed and tested. The model describes quantitative relationships between levels of genetic merit for the considered traits and levels of inputs and outputs of the farm, in relation to production circumstances. The model is restricted to calculation of economic values for milk and beef production traits and dry-matter intake capacity. Inputs and outputs of the herd are calculated from feed costs, other variable and fixed costs, and revenues from selling of milk and animals (beef). Intake of roughage and concentrate of lactating cows is based on the ratio between energy intake requirement and dry-matter intake capacity. Parameters of the model represent the Dutch Black and White population. However, parameters can easily be adapted in order to calculate economic values for different production circumstances or cattle populations. Moreover, the model can be used for calculation of parameters of biological efficiency of dairy cattle production systems.

1. INTRODUCTION

Economic values are major factors in choosing the traits to be included in the breeding goal (Harris, 1970). The economic value expresses to what extent improvement of genetic merit of a trait can contribute to an improvement of economic efficiency of animal production systems. Knowledge on the relationships between economic values in dairy cattle production and production circumstances is limited. Little attention has been given to influences of prices (Adelhelm et al., 1972), production levels (Zeddies et al., 1981) and milk production quota (Van Arendonk et al., 1985; Zeddies, 1985). More knowledge on the relationships between economic values and production circumstances is wanted to determine the need for a variety of breeding stocks as discussed by Smith (1985). Criteria for a diversification of production systems with different breeding objectives need to be established.

A model is developed to study to what extent economic values of production traits in dairy cattle breeding depend on production circumstances at

animal, herd, farm and sector level. The model describes quantitative relationships between levels of genetic merit for the considered traits and levels of inputs and outputs in relation to production circumstances.
The method of normative modelling is chosen, because it enables the user to vary relevant elements of the system independently. This paper describes the elements and their relationships within the model. In order to test the model, some simulated data are presented.

## 2. GENERAL CONCEPTS

The developed dairy farm model is deterministic and static. The herd enterprise is modelled in detail and includes dairy cows and young replacement stock. No variation in genetic merit between animals within the herd is assumed. Roughage production of the farm is defined in terms of only quality and cost price of roughages. Figure 1 shows input and output components of the model.
Milk revenues come from selling of carrier, fat and protein (carrier is milk without fat and protein). Beef revenues come from selling of new-born calves and disposed cows. Feed costs originate from concentrate and roughage

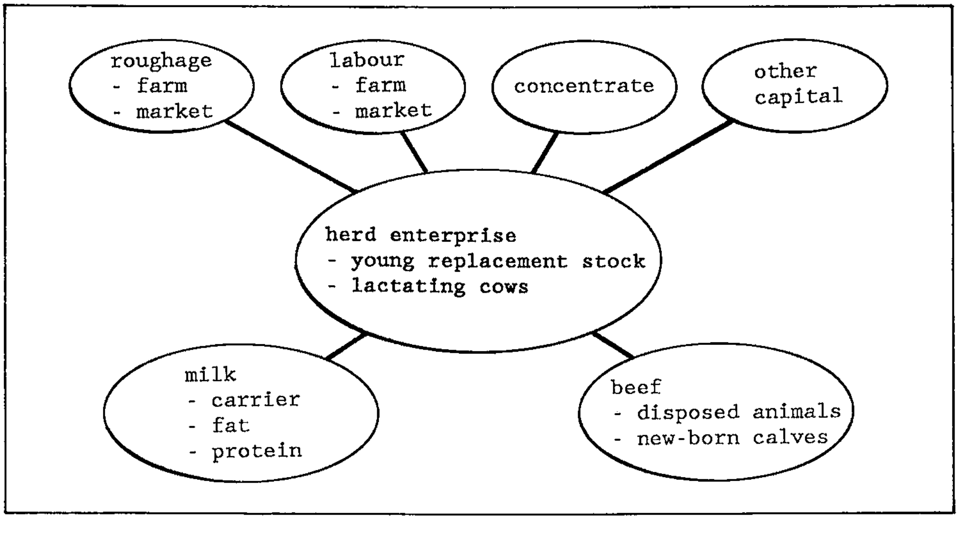


*Figure 1: Schematic representation of input and output components of the model.*

requirements of the herd. Concentrate has to be bought at the market. Roughage production of the farm is not changed when changing intake requirements of the herd. Therefore costs of roughage production (including costs of machinery land and labour) are fixed. Change in requirements for roughage of the herd will result in a higher or lower exchange between farm and market. Supply of labour by the farmer is considered to be fixed but, just like roughage, labour is freely exchangeable with the environment.

Within the concept of farm management, breeding is a tool for long-term (strategic) planning of production. Therefore marginal costs of buildings per additional cow place are treated as variable costs. Other variable costs include costs of health care, AI and interest. Costs of the herd enterprise not related to herd size are included in the fixed costs.

Outputs and inputs of the farm are calculated by equations (1) and (2).

---

$$\text{Outputs} = \text{milk revenues} + \text{beef revenues} \quad (\text{Dfl.year}^{-1}) \qquad (1)$$
$$= N * [p_{mib}MICC + p_{mif}MIFC + p_{mip}MIPC + p_{bec}BECC + p_{bed}BEDC]$$

$$\text{Inputs} = \text{feed costs} + \text{labour costs} + \text{other variable costs} + \text{fixed costs} \quad (\text{Dfl.year}^{-1}) \qquad (2)$$
$$= N * [p_c CC + p_{rm}RMC] + p_{rf}RF + N * p_{lm}LRC + p_{lf}LF + N * VCC + FCF$$

in which:

- N : number of average present lactating cows (aplc),
- MICC : milk carrier production level (kg.aplc$^{-1}$.year$^{-1}$),
- $p_{mib}$ : base price of milk (Dfl.kg$^{-1}$),
- MIFC : milk fat production level (kg.aplc$^{-1}$.year$^{-1}$),
- $p_{mif}$ : milk fat price (Dfl.kg$^{-1}$),
- MIPC : milk protein production level (kg.aplc$^{-1}$.year$^{-1}$),
- $p_{mip}$ : milk protein price (Dfl.kg$^{-1}$),
- BECC : production new-born calves (kg.aplc$^{-1}$.year$^{-1}$),
- $p_{bec}$ : weighed price of new-born calves (Dfl.kg$^{-1}$),
- BEDC : production disposed animals (kg.aplc$^{-1}$.year$^{-1}$),
- $p_{bed}$ : weighed price of disposed animals (Dfl.kg$^{-1}$),
- CC : concentrate requirements (MJ $NE_l$.aplc$^{-1}$.year$^{-1}$),
- $p_c$ : price of concentrate (Dfl.MJ $NE_l^{-1}$),
- RMC : amount of purchased roughage (MJ $NE_l$.aplc$^{-1}$.year$^{-1}$),
- $p_{rm}$ : price of roughage on the market (Dfl.MJ $NE_l^{-1}$),

| | | |
|---|---|---|
| RF | : | amount of roughage grown on the farm (MJ $NE_l.year^{-1}$), |
| $p_{rf}$ | : | costs of roughage grown on the farm (Dfl.MJ $NE_l^{-1}$), |
| LRC | : | labour attracted from the market ($hour.aplc^{-1}.year^{-1}$), |
| $p_{lm}$ | : | price of labour on the market ($Dfl.hour^{-1}$), |
| LF | : | amount of labour supplied by the farmer ($hour.year^{-1}$), |
| $p_{lf}$ | : | price of labour supplied by the farmer ($Dfl.hour^{-1}$), |
| VCC | : | other variable cost ($Dfl.aplc^{-1}.year^{-1}$), |
| FCF | : | other fixed costs ($Dfl.year^{-1}$). |

Using equation (1) and (2), different efficiencies of production can be defined: (outputs/inputs), (inputs/outputs) or (outputs - inputs). Given a basic situation, the economic value of a trait can be calculated as the change in efficiency due to a marginal change in genetic merit for the trait.

It is assumed that marginal changes of genetic merit do not result in changed 'other variable costs' and labour requirements per cow. Unless additional restrictions on inputs or outputs are stated, herd size is not changed after marginal improvement of genetic merit. Restrictions can be stated in order to deal with production-factor input or product output limitations at farm level (e.g. milk production quotas).

Parameters of the model are chosen to represent the Black and White population in The Netherlands. Price parameters chosen represent average price levels in The Netherlands for the period 1985-86. By changing parameters, the model can easily be adapted for use in other production circumstances or cattle populations. Seasonal variation in animal performance (milk production, feed intake) and prices are not included in the model.

## 3. ELEMENTS OF THE MODEL

### 3.1. Studied characteristics

The model is restricted to study milk and beef production traits and dry-matter intake capacity:

- milk production traits (age at first calving is 24 months):
  - fat production of a first-parity cow in a 305-day lactation;
  - protein production of a first-parity cow in a 305-day lactation;
  - carrier production (i.e. milk without fat and protein) of a first-parity cow in a 305-day lactation.
- beef production traits:
  - birth weight of a female calf born as the first calf of a cow;
  - mature live weight of a cow.
- dry-matter intake capacity: basic intake capacity of dry-matter of a reference feed ($kg.day^{-1}$) for a cow in second month of the third lactation, weighing 600 kg, yielding 6000 kg in a 305-day lactation period.

Starting values of genetic merit for milk production traits are set equal to 4655, 219 and 171 kilogram carrier, fat and protein, respectively (corresponding to 5045 kilogram milk, 4.34% fat and 3.38% protein; NRS, 1987). Birth weight is set equal to 36 kilogram, and mature weight to 600 kilogram (Meijering and Postma, 1985; Van Arendonk, 1985[a]). Basic dry-matter intake capacity was 16.30 kilogram per day (paragraph 3.2.4.2.).

### 3.2. Animal level

At the animal level, input and output components per animal are simulated. Modelling includes simulation of:
- live weight;
- feed intake of young replacement stock;
- milk production;
- feed intake of lactating cows:
  - energy intake requirement;
  - dry-matter intake capacity;
  - composition of feed intake;
- beef production (in terms of carcass value).

According to systematic non-genetic effects, input and output levels are calculated for subsequent age periods. A heifer calves at a fixed age of 24 months (732 days). The calving interval is set equal to 12 months. This implies a lactation period of 10 months, a dry period of 2 months and 88 days open. Live weight, milk production, feed intake and carcass value of lactating cows are simulated on a monthly basis. No loss of production for animals disposed involuntarily is assumed.

### 3.2.1. Live weight

The Von Bertalanffy-curve, combined with adjustment for gestation and lactation effects is used to determine the live weight of animals (Korver et al., 1985).

$$LW_{t_a t_l t_p} = f(age) + f(lactation) + f(pregnancy) \quad (kg)$$

$$= LWAGE_{t_a} + LWLAC_{t_l} + LWPRE_{t_p}$$

$$= A*[1-(1-(YM/A)^{1/3})e^{-kt_a}]^3 + p_1 t_l p_2^{-1} e^{(1-t_l p_2^{-1})} + p_3^{3} t_{pc}^{3} \qquad (3)$$

in which:

- $LW_{t_a t_l t_p}$ : live weight of a $t_a$ days old animal at $t_l$ days in lactation and $t_p$ days pregnant (kg),
- A : mature live weight (kg),
- YM : birth weight (kg),
- k : growth parameter,
- $p_1$ : maximum decrease of live weight during lactation (kg),
- $p_2$ : moment in lactation with minimum live weight (days),
- $p_3$ : pregnancy parameter,
- $t_{pc}$ : $t_p$ - 50 when $t_p - 50 > 0$, otherwise $t_{pc} = 0$.

Parameters are given by Van Arendonk (1985[a]) based on Bakker and Koops (1977) and Korver et al. (1985): k, $p_2$ and $p_3$ are set equal to .0028, 75 days and .0187, respectively. $p_1$ is set equal to -25.0, -37.5 and -50.0 kg for first, second and third and later lactations, respectively. YM is set equal to the average birth weight of female calves born in the herd. The actual weight of new-born calves depends on average age of the dams. Relationships (equation (4)) are based on Meijering and Postma (1985).

$$Y(parity\ 2) = Y(parity\ 1) + 3.75 \quad (kg) \qquad (4)$$

$$Y(parity>2) = Y(parity\ 1) + 5.45 \quad (kg)$$

Different parameters for birth and mature weight are used to simulate growth of male calves to be sold at an early age (Meijering and Postma, 1985; Taylor and Murray, 1987):

$$Y(male) = Y(female) + 3.08 \quad (kg) \qquad (5)$$
$$A(male) = A(female) + 300. \quad (kg)$$

Y(parity 1) and A(female) are studied characteristics describing the population and are, therefore, starting points in simulating live weight.

### 3.2.2. Feed intake of young replacement stock

Energy requirement for maintenance is simulated by equation (6). Simulation of energy requirement for tissue growth is based on equation (7).

$$ERMR_{t_a} = FERM * \sum_{t=1}^{t=t_a} (LW_{t_a t_1 t_p})^{.75} \quad (MJ\ NE_1) \qquad (6)$$

$$ERGR_{t_a} = ERG * (LWAGE_{t_a} - YM) \quad (MJ\ NE_1) \qquad (7)$$

in which:

- $ERMR_{t_a}$ : energy requirement for maintenance during the rearing period until $t_a$ days of age (MJ $NE_1$),
- $ERGR_{t_a}$ : energy requirement for growth during the rearing period until $t_a$ days of age (MJ $NE_1$),
- FERM : factor energy requirement for maintenance (MJ $NE_1.day^{-1}.kg^{-.75}$),
- $LW_{t_a t_1 t_p}$ : live weight (see equation (3); kg),
- $LWAGE_{t_a}$ : age-dependent live weight (see equation (3); kg),
- ERG : average energy requirement per kilogram growth during the rearing period (MJ $NE_1.kg^{-1}$),
- YM : average birth weight of female calves born in the herd (kg).

FERM is set equal to .2927 (MJ $NE_1.day^{-1}.kg^{-.75}$), corresponding to the maintenance requirement of mature cows (Van Es, 1978). ERG is set equal to 17.26 MJ $NE_1.kg^{-1}$, which is an approximate value derived from requirements

*Table 1: Energy-requirement for pregnancy (MJ $NE_l$ per month pregnant) (Van Arendonk, 1985[a]).*

| | month | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| MJ $NE_l.day^{-1}$ | .00 | .00 | .37 | 1.41 | 3.17 | 5.63 | 8.80 | 12.68 | 17.26 |

of young cattle given by CVB (1986). Energy requirement for pregnancy is given by Van Arendonk (1985[a]), based on Van Es (1978) (tabel 1). The effect of pregnancy on maintenane requirements is accounted for in equation (7). To determine feed intake during rearing period it is assumed that 10% of total energy requirement is supplied by concentrate and 90% by roughage intake.

### 3.2.3. Milk production

The starting point in the simulation of milk production is the genetic merit of a first-parity cow in a 305-days lactation for fat, protein and carrier. Using multiplicative adjustment factors (Wilmink, 1985), given in table 2, milk, fat and protein production in second and later lactations are simulated. These factors are adjusted for influences of selection and genetic progress (Wilmink, 1985). Production for each month of lactation is simulated. Coefficients for relative milk production (Van Arendonk, 1985[a]) are calculated assuming 88 days open and excluding seasonal effects (table 3). Monthly production for amounts of fat and protein are simulated using additive adjustment factors for fat and protein percentages (Wilmink, 1985) (table 4). Monthly production of fat-protein-corrected-milk (FPCM) is calculated using equation (8) (based on Korver, 1982).

$$FPCM = .349*CARRIERprod + 11.049*FATprod + 7.049*PROTEINprod \quad (kg) \quad (8)$$

Milk production characteristics are defined on a first lactation basis. Marginal selection response in later lactations for fat, protein and milk production are simulated using a genetic correlation between first and later lactations of .91 (Meyer, 1984).

*Table 2: Multiplicative adjustment factors for age at calving for milk, fat and protein yield (Wilmink, 1985).*

| lactation number | milk | fat | protein |
|---|---|---|---|
| 1 | 1.000 | 1.000 | 1.000 |
| 2 | 1.182 | 1.184 | 1.215 |
| 3 | 1.284 | 1.281 | 1.302 |
| 4 | 1.334 | 1.326 | 1.339 |
| 5 | 1.350 | 1.334 | 1.350 |
| 6 | 1.355 | 1.333 | 1.351 |
| 7 | 1.347 | 1.319 | 1.339 |
| 8 | 1.338 | 1.302 | 1.325 |
| 9 | 1.324 | 1.278 | 1.305 |
| 10 | 1.305 | 1.250 | 1.280 |
| 11 | 1.284 | 1.217 | 1.252 |
| 12 | 1.256 | 1.178 | 1.217 |

### 3.2.4. Feed intake of lactating cows

Only expenses necessary for and quantitatively related to production are considered to be costs. Therefore energy intake is set equal to energy intake requirement and energy has to be supplied in its cheapest form.
It is assumed that energy intake by concentrate is more expensive than energy intake by roughage. This implies that roughage intake has to be maximized. Within the model, composition of feed intake is determined by

*Table 3: Relative production (%) in each month in lactation for different parities for 88 days open excluding the effect of season (Van Arendonk, 1985[a]).*

| | month | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| parity | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | 11.55 | 12.81 | 12.18 | 11.51 | 10.83 | 10.16 | 9.49 | 8.62 | 7.22 | 5.63 |
| 2 | 12.51 | 13.36 | 12.55 | 11.71 | 10.87 | 10.02 | 9.18 | 8.15 | 6.64 | 5.01 |
| 3 | 13.26 | 13.79 | 12.85 | 11.87 | 10.89 | 9.91 | 8.93 | 7.78 | 6.19 | 4.53 |

*Table 4: Additive adjustment factors for the effect of month in lactation on fat and protein percentages in milk (Wilmink, 1985).*

| | month 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| fat % | .00 | -.24 | -.25 | -.21 | -.14 | -.06 | .04 | .15 | .29 | .38 |
| protein % | .00 | -.18 | -.15 | -.08 | -.00 | .08 | .15 | .21 | .26 | .30 |

energy intake requirement, dry-matter intake capacity and feed quality.

### 3.2.4.1. Energy intake requirement

Energy intake requirement of lactating cows is a function of requirements for maintenance, milk production, growth, pregnancy and mobilization and restorage of body(-fat) tissue.

Simulation of the monthly energy requirement for maintenance and milk production for mature cows is based on equation (9) (Korver, 1982).

$$ER_{ij} = (.293*LW_i^{.75} + 3.05 * FPCM_{ij}) * (.975 + .00165 * FPCM_{ij}) \quad (MJ\ NE_l.day^{-1}) \qquad (9)$$

in which:

- $ER_{ij}$ : average energy requirement for maintenance and milk production in month i, lactation j (MJ $NE_l.day^{-1}$),
- $LW_i$ : live weight at first day month i (see equation (3); kg),
- $FPCM_{ij}$ : average FPCM production month i, lactation j ($kg.day^{-1}$).

Equation (9) applies to housed animals. To include requirements for grazing during summer, energy requirements for maintenance are adjusted by + 10% (Meijs, 1981). Additional requirements for age-dependent growth are calculated by using equation (3), and are set equal to 18.64 and 20.71 MJ $NE_l$ per kilogram of live weight gain for first calf and older cows, respectively. Energy mobilized and restored during lactation is calculated from f(lactation), assuming every kilogram of mobilized tissue to supply 17.61 MJ $NE_l$ and every kilogram of tissue to be restored demanding 20.71 MJ

$NE_1$ (Van Es, 1978; Van Arendonk, 1985[a]). During the dry period energy requirement for age dependent growth and restorage of body tissues is 10% higher (Van Es, 1978). Additional requirements for development of the foetus are given in table 1.

### 3.2.4.2. Dry-matter intake capacity

Modelling of dry-matter intake capacity consideres the factors (Bines, 1979) size and milk yield of the cow, composition and physical form of the diet. Mean capacity for the entire lactation for cows yielding on average 5000 kg FPCM in 305 days of lactation equals .135 kg dry-matter per kg metabolic weight per day (ARC, 1980). Adjustment for higher yields is .2 kg dry-matter per day per kg FPCM. Multiplicative adjustment factors for specific months in lactation are given by ARC (1980) (table 5). Based on Brown et al. (1977), correction for the deviation of average daily milk yield per lactation month from average lactation yield is included.
Capacity is converted to dry-matter intake capacity of a reference feed: pasture grass cut at the grazing stage of first growth (25 % crude fiber, 15 % crude protein and .95 UFL net energy value per kg dry-matter; Jarrige et al., 1986). The conversion factor is calculated from the levels of intake capacity of the standard cows of ARC (1980) and Jarrige et al. (1986) and equals .9. By the use of 'fill values' it is defined to what extent intake of a given feed takes up dry-matter intake capacity of reference feed ([kilogram dry-matter reference grass].[kilogram dry-matter feed]$^{-1}$).

$$DMIC_{ij} = \{[.135 * LWAGE_{.j}^{\;.75} + .20 * (FPCM_{.j} - 5000/305)] * DMIM_{i} + .20 * (FPCM_{ij} - FPCM_{.j})\} * .9 \qquad (10)$$

(kg dry-matter intake of reference pasture grass.day$^{-1}$)

in which:

- $DMIC_{ij}$ : dry-matter intake capacity in month i and lactation j in kg dry-matter of a reference pasture grass.day$^{-1}$,
- $LWAGE_{.j}$ : mean age-dependent live weight during lactation j (see equation (2), kg);

*Table 5: Multiplicative adjustment factors for the effect of month in lactation on dry-matter intake capacity (ARC, 1980).*

| month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11[i] | 12[i] |
| .81 | .98 | 1.07 | 1.08 | 1.09 | 1.08 | 1.01 | .99 | .97 | .93 | .90 | .90 |

*i: dry period: no reference available*

$FPCM_{.j}$ : mean FPCM production level during lactation j ($kg.day^{-1}$),

$FPCM_{ij}$ : mean FPCM production level during month i and lactation j ($kg.day^{-1}$),

$DMIM_i$ : multiplicative adjustment factor for month i in lactation on dry-matter intake capacity.

---

The level of basic dry-matter intake capacity of reference feed for a cow in the second month of the third lactation, weighing 600 kg and yielding 6000 kg milk (4.2% fat and 3.4% protein) in a 305-day lactation period, is calculated. This level equals 16.30 $kg.day^{-1}$.. In order to be able to vary basic dry-matter intake capacity, as a genetic merit trait, equation (10) is rewritten in the following way:

---

$$DMIC_{ij} = \{.135 * LWAGE_{.j}^{.75} + .20 * (FPCM_{.j} - 5000/305)) * DMIMi + .20 * (FPCM_{ij} - FPCM_{.j})\} * .9 + (DMIC_{base} - 16.30) * DMIM_i/DMIM_2 \qquad (11)$$

in which:

$DMIC_{base}$ = basic dry-matter intake capacity of reference feed for a cow in second month of the third lactation, weighing 600 kg and yielding 6000 kg milk (4.2% fat and 3.4% protein) in a 305-day lactation period ($kg.day^{-1}$).

(For other symbols, see equation (10).)

---

**3.2.4.3. Composition of feed intake**

The model distinguishes two kinds of feeds: roughage and concentrate. Energy content and fill value of roughage are 6.21 MJ $NE_l$ per kilogram dry-matter

(CVB, 1986) and 1.1 (Jarrige et al., 1986), respectively. Quality of roughage purchased is equal to roughage produced on the farm. The subtitution rate of concentrate for reference pasture grass is given by Achten and Tollens (1986), equation (12).

$$SR = .26 * CL + .023 * CL^2 \quad (12)$$

in which:

SR : total substitution or total fill value for reference pasture grass intake capacity (kg dm reference grass).(CL kg dm concentrate)$^{-1}$,

CL : concentrate level (kg dry-matter.day$^{-1}$).

In this model concentrate can be entered in the diet by units of .1 kg dry-matter.day$^{-1}$. Minimum intake of concentrate is set equal to 2. kg and 1. kg dry-matter per day during lactation and dry period, respectively. Energy content of concentrate is set equal to 7.21 MJ $NE_1$ per kilogram dry-matter.

### 3.2.5. Beef production

Beef production of a dairy farm consists of disposal of new-born calves, young replacement stock and lactating cows (both voluntary and involuntary). Live weight of disposed animals is simulated using equation (3). Prices per kilogram live weight for lactating cows depend on dressing percentage and carcass quality, and are therefore influenced by lactation number and stage of lactation (Van Arendonk et al., 1984). Adjustment factors for dressing percentage and price per kilogram carcass are given in table 6 (Van Arendonk, 1985[a]). Prices of young replacement stock were based on price per kilogram live weight of a first-parity cow 210 days in lactation. For new-born calves, prices were stated independently of qualitative meat production characteristics.

## 3.3. Herd level

At the herd level, relative numbers of animals within the different age

*Table 6: The effect of age at calving and stage of lactation on dressing percentage (D%) and the deviation in price per kg carcass weight (dp, Dfl) (Van Arendonk, 1985[a]).*

| | lactation number | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| D% | 50. | 49.8 | 49.6 | 49.4 | 49.3 | 49.2 | 49.1 | 49.0 | 48.9 | 48.7 | 48.5 | 48.2 |
| dp | .00 | -.05 | -.07 | -.10 | -.15 | -.20 | -.25 | -.30 | -.40 | -.50 | -.60 | -.70 |

| | lactation month[i] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| D% | .20 | -.60 | -.60 | -.60 | -.60 | -.40 | -.20 | .00 | .20 | .40 | .60 | .20 |
| dp | .05 | -.20 | -.20 | -.20 | -.15 | -.10 | -.05 | .00 | .05 | .10 | .10 | .05 |

*i: value at the beginning of each month*

classes are simulated (herd composition). In total 14 age classes are simulated, each having 12-month duration: 2 one-year rearing periods and 12 lactations (including 2-month dry period). Marginal probabilities of involuntary disposal of replacement young stock are given by Hibma (1983) (table 7). It is assumed that two-thirds of the disposal of animals during the second year is because of insufficient fertility. Marginal probabilities of involuntary and voluntary replacement for lactating cows are given by Van Arendonk (1985[b]) (table 7). Although it is assumed that all animals have equal genetic merit, voluntary replacement is modelled in order to obtain a realistic herd composition. Marginal probalilities of replacement given by Van Arendonk (1985[b]) represent an optimum replacement policy, assuming a fixed calving interval.

Infertile young females are sold at an age of 22 months. Other replacement during the rearing period is at average ages of 6 and 18 months for first and second year, respectively. Selling of male calves and female calves not needed for replacement takes place at an age of 7 days. It is assumed that, on average, 95% of the cows calving bear a calf that can be sold (Meijering and Van Eldik, 1981). 50% of the calves born are male calves. Disposal of lactating cows for both involuntary and voluntary replacement takes place at 7 months in lactation (Van de Venne, 1987). According to the moment of

*Table 7: Marginal probabilities (%) of voluntary and involuntary replacement (Hibma, 1983; Van Arendonk, 1985[b]) and simulated herd composition (%).[i]*

| lactation number | replacement involuntary | replacement voluntary | herd composition |
|---|---|---|---|
| -[ii] | 8.0 | 0.0 | 29.2 |
| - | 8.0 | 0.0 | 26.9 |
| 1 | 13.6 | 6.2 | 24.8 |
| 2 | 14.9 | 2.7 | 19.9 |
| 3 | 17.9 | 2.6 | 16.4 |
| 4 | 19.8 | 3.7 | 13.0 |
| 5 | 22.7 | 5.9 | 9.9 |
| 6 | 24.5 | 9.3 | 7.1 |
| 7 | 25.9 | 17.6 | 4.7 |
| 8 | 27.3 | 26.8 | 2.7 |
| 9 | 29.0 | 43.9 | 1.2 |
| 10 | 31.0 | 51.6 | 0.3 |
| 11 | 32.6 | 60.4 | 0.1 |
| 12 | 34.5 | 65.5 | 0.0 |

*i : herd composition as a percentage of the total number of calving cows.*
*ii: rearing period.*

disposal, the number of average present lactating cows was expressed as a percentage of the total number of cows calving.

The model gives the option to use beef bulls for terminal crossing. Percentage of beef crossing equals the percentage of female calves (alive at 7 days of age) not needed for replacement within the herd. All female and male cross-bred calves are sold as new-born calves. Weights of cross-bred new-born calves are 2 kilograms higher than those of pure-bred calves of the same sexe and parity group of the dam. The model also gives the option of excluding young replacement stock from the herd enterprise, combined with buying (pregnant) replacement heifers.

### 3.4. Price elements farm and sector level

At the farm level, relative numbers of animals within each age class are first combined with corresponding levels of production and need for production-factors. These calculated inputs and outputs of the farm are then valued. Inputs and outputs are expressed on a 'per average present lactating cow (aplc) per year' basis (see equation (1)).

The mean costs of roughage grown on the farm ($p_{rf}$, equation (1)) are set equal to .043 Dfl.MJ $NE_1^{-1}$. This price is based on figures presented by Van Horne and Sturkenboon (1985).

Sundries (AI, health control, interest) are set equal to 540 Dfl per reared heifer (Van Horne and Sturkenboom, 1985) and 425 Dfl.$aplc^{-1}$ (Van Arendonk et al., 1985). Variable costs of buildings are set equal to 750 Dfl and 455 Dfl per reared heifer and aplc, respectively (IDS, 1987). Variable labour requirements are assumed to be 11.8 and 23.2 houres per reared heifer and aplc, respectively (Wieling, 1981; Handboek voor de rundveehouderij, 1984).

At the sector level, prices of products and production-factors on the market are determined.

In The Netherlands, milk price is based on fat and protein amount, with a negative base price for carrier amount. Milk prices (Dfl.$kg^{-1}$) are given by Voets and Zee (1986): base price milk ($p_{mib}$) - .02, milk fat price ($p_{mif}$) 9.31, milk protein price ($p_{mip}$) 11.01.

Major factors determining values of new-born calves on the Dutch market are breed, sex and live weight.

Average price of new-born female calves of the Black and White breed is set at 7.77 Dfl.$kg^{-1}$ live weight (Boerderij, 1986). On average, male calves are priced 4.18 Dfl.$kg^{-1}$ higher than female calves. Cross-bred calves are priced 2.00 Dlf.$kg^{-1}$ higher than pure-bred calves of the same sex. Base price of beef is set equal to 6.97 Dfl.(kg carcass weight)$^{-1}$ for a first-parity cow 210 days in lactation (Boerderij, 1986). This price represents an average price of a first-class quality Black and White cow. Price of pregnant replacement heifers is set equal to 2250 Dfl (Boerderij, 1986).

Concentrate price is given by LEI (1985): .072 Dfl.MJ $NE_1^{-1}$ ($p_c$). Roughage price on the market is set equal to an average price of maize silage: .071 Dfl.MJ $NEl^{-1}$ ($p_{rm}$) (LEI, 1985). For the basic situation, it is assumed that there is a surplus in supply of labour from the farmer. In order to account

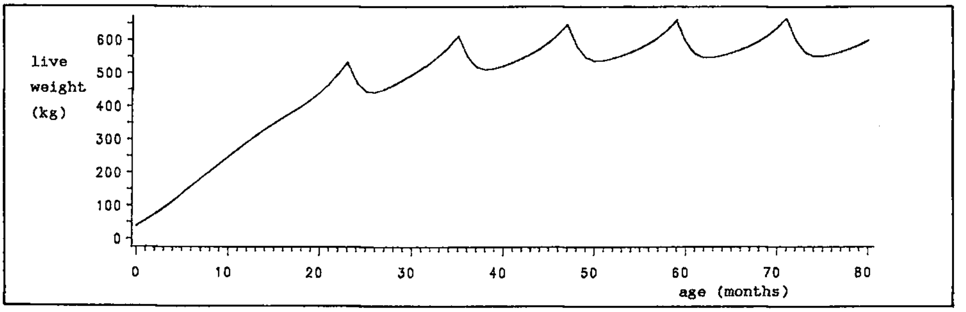

*Figure 2: Simulated live weight curve of a cow.*

for the fact that saved labour can only partly be used in other production sectors, the market price of labour is set equal to a low price of 12.50 $Dfl.hour^{-1}$ ($p_{lm}$).

## 4. MODEL TESTING

Simulated herd composition is presented in table 7. Over 60% of the female calves have to be kept on the farm for replacement. Figure 2 shows simulated live weight for a cow from birth up to 75 months of age. Figure 2 closely resembles figures presented by Bakker and Koops (1977) and Korver et al. (1985). The average birth weight of female calves is 39.8 kilograms. After first calving, a heifer weighs about 80% of the mature live weight. On average, 33.9 kilograms of new-born calf equivalent per average present cow per year is sold (BECC equation (1)). Average live weight of lactating cows equals 557 kilograms. 153 kilograms (per year) of disposed young replacement stock and lactating cows is sold per average present cow.
Total energy requirements to grow a heifer from birth to moment of first calving are 24700 MJ $NE_1$. This value corresponds to figures presented by Handboek voor de Rundveehouderij (1984). About 60% of these requirements are maintenance requirements. Average production level per cow per year is 6512, 280 and 222 kilograms of milk, fat and protein, respectively. Average roughage and concentrate intake amounts to 26779 MJ $NE_1$ and 9584 MJ $NE_1$, respectively, per lactating cow per year. Figure 3 shows the energy intake pattern over the lactation. This pattern corresponds to intake patterns given by Korver (1982). Energy intake and intake of roughage and concentrate

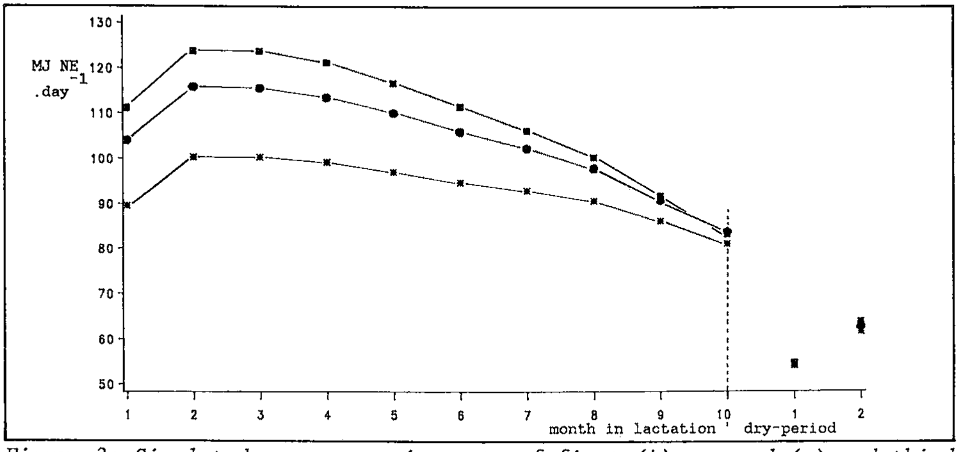


*Figure 3: Simulated energy requirements of first (*), second (●) and third (■) parity cows.*

during lactation is given in figure 4. First, total dry-matter intake is at a maximum and, secondly, roughage dry-matter intake. Moments in lactation of maximum intake correspond to figures given by Journet and Remond (1976) for a diet with ad libitum maize silage and a high level of concentrate. The total energy requirement of a third-parity cow equals 36763 MJ $NE_1$, of which 1504 MJ $NE_1$ for development of the foetus, 235 MJ $NE_1$ is for age-dependent growth, 17.5 MJ $NE_1$ is for the body-fat mobilization-restorage process, 13939 MJ $NE_1$ is for maintenance and 20910 MJ $NE_1$ is for milk production. Her production equals 6754 kilogram FPCM, which means an overall biological efficiency of 36763/6754 = 5.44 MJ $NE_1.kg\ FPCM^{-1}$.

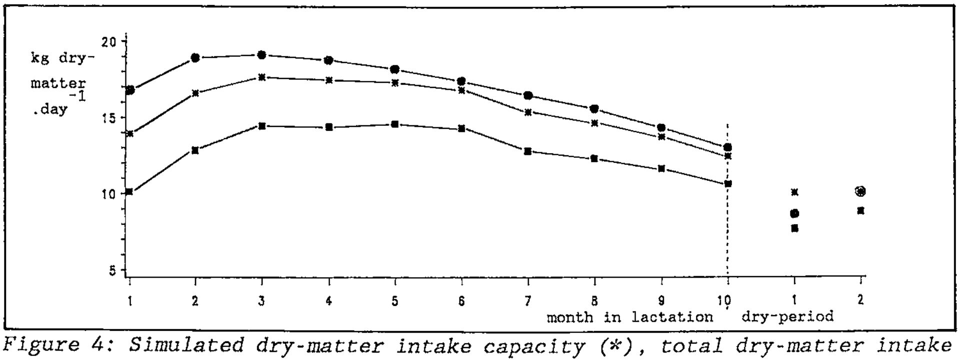


*Figure 4: Simulated dry-matter intake capacity (*), total dry-matter intake (●) and dry-matter intake for roughage (■) of a third parity cow.*

## 5. DISCUSSION

The model calculates quantitative amounts of output for different categories of animals. Assuming, that improvement of qualitative beef production characteristics or fattening characteristics will result in higher animal prices, the model can be used to quantify influences of changes in beef revenues of the dairy farm according to the level of genetic merit of qualitative beef production traits. However, influences of improvement of qualitative beef production traits on changes in energy requirement for growth and maintenance are not accounted for directly within the model.
The model does not account for higher energy requirements for pregnancy when raising birth weight. This means, that the economic value of birth weight might be slightly over-estimated.
The genetic correlation is included in calculating correlated response in later lactations, when improving first lactation yield. Therefore genetic correlations between first and later lactations have to be omitted when calculating cumulative discounted expressions for milk production traits (Brascamp, 1973).
The model is developed to study to what extent economic values in cattle breeding depend on production circumstances. This means that a sensitivity analysis for parameters within the model will be performed. Of main interest are sensitivity of economic values towards changes in prices and elements that influence quantitative relationships between levels of genetic merit and levels of inputs and outputs.
Using statements of additional restrictions on inputs or outputs, the model is able to calculate direct values according to the rescaling-method proposed by Smith _et al._ (1986).
It is possible to use the model to calculate parameters of biological efficiency of dairy cattle production systems. Using the model, influences of, for example, production level on biological efficiency can be quantified.

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Chapter three

# Economic values in cattle breeding. I. Influences of production circumstances in situations without output limitations.

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**ABSTRACT**

This study discusses sensitivity of economic values of milk and beef production traits in cattle breeding to production circumstances, in situations without output limitations at the farm level. It is concluded, that prices of products and production-factors are of decisive importance in determining relative economic importance of improvement of milk and beef production traits. Influences of prices originate from influences on the values of marginal inputs and outputs and influences on the quantaties of marginal inputs and outputs via optimization of farm management. Production levels and feed quality have no noteworthy influence on economic values of milk and beef production traits. The change in economic efficiency when increasing mature body weight is small and negative.

## 1. INTRODUCTION

Relative economic values, genetic potentials of improvement of traits (e.g. heritabilities) and possibilities of accurate measurement of genetic means (e.g. recording costs in labour, facilities and time) determine the definition of the breeding goal (Harris, 1970). Smith (1985, 1986) discussed the need for a variety of breeding goals to meet the range in production circumstances. Production circumstances may influence the three aspects that determine the breeding goal. For example, genetic variances depend on production levels and this may lead to a level dependent breeding goal (Dommerholt and Wilmink, 1986). Knowledge on the relationships between production circumstances and economic values is limited. The economic value expresses to what extent improvement of genetic merit of a trait contributes to an improvement of economic efficiency of the production system. Efficiency of a production system is a function of the inputs (production-factors) and the outputs (products) of the system. To calculate economic values, changes in outputs and inputs, due to changes in genetic merit need to be quantified and valued. Production circumstances may have their impacts on quantities and values of the changes in outputs and inputs. Incorrect economic values and ommission of important traits out of the breeding goal may reduce efficiency of improvement of animal production (Smith, 1983).

Adelhelm et al. (1972) used a linear programming model to calculate influences of different farm types (among others herd size, costs of buildings) and price alternatives on the economic values. The economic values of milk production traits (fat-free milk and fat production) were influenced by milk prices and price of concentrate. The economic value of carcass composition was influenced by beef prices. Farm types only influenced economic values of feed conversion (fattening period), herd life and lactation length.

Zeddies et al. (1981) defined a model to calculate economic values of fat-corrected-milk (fcm) depending on milk production level and live weight. Milk production level influenced the ratio by which marginal energy requirements had to be supplied by concentrate and roughage. Higher production levels gave rise to higher marginal needs for concentrate. However, these influences were small and hardly influenced the economic value of fcm. Effects of level of live weight on the economic value of fcm were found to be small.

Limitations on milk outputs at farm level change economic values of milk production traits (Van Arendonk et al., 1985; Zeddies, 1985).

Knowledge on the relationships between production circumstances and economic values needs to be extended in terms of other traits and other production circumstances.

The aim of this study is to determine the sensitivity of economic values of milk and beef production traits in cattle breeding to production circumstances. In this paper, sensitivity of economic values in situations without limitations is discussed. Situations with output limitations are discussed in a subsequent paper (Groen, 1989).

## 2. METHOD

The economic value of a trait is defined as 'the change in profit of the farm expressed per average present lactating cow per year, as a consequence of one unit of change in genetic merit of the trait considered'. Modelling at the farm level is thought to give good insight into the sensitivity of economic values towards production circumstances at animal, herd, farm and higher levels. Choice of the interest of selection (definition of efficiency function), profit (= outputs - inputs) maximization, corresponds to the general interest of individual farms. The term 'unit' will have to be detailed per trait (e.g. kilogram per lactation when considering milk production traits). In calculating economic values, genetic merit of the trait considered is to be changed without changing levels of any other trait.

The model described by Groen (1988) is used to calculate economic values. This deterministic and static dairy farm model is developed to study to what extent economic values of production traits in dairy cattle breeding depend on production circumstances. Outputs and inputs of the farm are calculated from selling of milk and beef (animals) and from feed costs, labour costs and other variable and fixed costs (equations (1) and (2)). Fixed costs include all costs that are fixed (constant or discontinuously variable) with respect to the size of the farm. Animal breeding is part of the management field of strategic (long term) planning of production. Therefore, all costs (although partly fixed with respect to size of the farm) are regarded variable with respect to time.

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$$\text{Outputs} = \text{milk revenues} + \text{beef revenues} \quad (\text{Dfl.year}^{-1}) \qquad (1)$$

$$= N * [p_{mib}MICC + p_{mif}MIFC + p_{mip}MIPC + p_{bec}BECC + p_{bed}BEDC]$$

$$\text{Inputs} = \text{feed costs} + \text{labour costs} + \text{other variable costs} + \text{fixed costs} \quad (\text{Dfl.year}^{-1}) \qquad (2)$$

$$= N * [p_cCC + p_{rm}RMC] + p_{rf}RF + N * p_{lm}LRC + p_{lf}LF + N * VCC + FCF$$

in which:

- N : number of average present lactating cows,
- MICC : milk carrier production level ($kg.cow^{-1}.year^{-1}$),
- $p_{mib}$ : base price of milk ($Dfl.kg^{-1}$),
- MIFC : milk fat production level ($kg.cow^{-1}.year^{-1}$),
- $p_{mif}$ : milk fat price ($Dfl.kg^{-1}$),
- MIPC : milk protein production level ($kg.cow^{-1}.year^{-1}$),
- $p_{mip}$ : milk protein price ($Dfl.kg^{-1}$),
- BECC : beef production new-born calves ($kg.cow^{-1}.year^{-1}$),
- $p_{bec}$ : price of new-born calves ($Dfl.kg^{-1}$),

BEDC : beef production disposed animals ($kg.cow^{-1}.year^{-1}$),

$p_{bed}$ : price of disposed cows ($Dfl.kg^{-1}$),

CC : concentrate requirements ($MJ\ NE_1.cow^{-1}.year^{-1}$),

$p_c$ : price of concentrate ($Dfl.MJ\ NE_1^{-1}$),

RMC : amount of purchased roughage ($MJ\ NE_1.cow^{-1}.year^{-1}$),

$p_{rm}$ : price of roughage on the market ($Dfl.MJ\ NE_1^{-1}$),

RF : amount of roughage grown on the farm ($MJ\ NE_1.year^{-1}$),

$p_{rf}$ : costs of roughage grown on the farm ($Dfl.MJ\ NE_1^{-1}$),

LRC : labour attracted from the market ($hour.cow^{-1}.year^{-1}$),

$p_{lm}$ : price of labour on the market ($Dfl.hour^{-1}$),

LF : amount of labour supplied by the farmer ($hour.year^{-1}$),

$p_{lf}$ : price of labour supplied by the farmer ($Dfl.hour^{-1}$),

VCC : other variable cost ($Dfl.cow^{-1}.year^{-1}$),

FCF : fixed costs farm ($Dfl.year^{-1}$).

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In this paper, a description of the principles of the model is given. Detailed information on parameters and justification of assumptions is given by Groen (1988).

The simulated herd includes young replacement heifers and lactating cows. From marginal probabilities of disposal, relative numbers of animals in different age-classes and numbers of animals disposed are calculated. Twelve subsequent one-year lactations are distinguished: ten months in lactation and two months dry-period. Inputs and outputs are simulated per individual animal in each age-class. Total farm outputs and inputs are calculated by multiplication of numbers of animals in each age-class and levels of inputs and outputs per animal in the corresponding age-class.

Starting point in simulating milk production is the genetic merit of a first-parity cow in a 305-day lactation for carrier (i.e. milk without fat and protein), fat and protein. Using adjustment factors and coefficients of relative production, monthly productions for carrier, fat and protein are simulated. The Von-Bertalanffy curve, combined with adjustment for gestation and lactation effects, is used to determine live weight of the animals. The curve parameters birth weight and mature weight are starting points in simulating live weight. Revenues of output of new-born calves are calculated from live weights at 7 days of age. Revenues of output of disposed young

replacement heifers and disposed lactating cows are calculated from live weights at moment of disposal, taking into account the effect of age and lactation on dressing percentage and carcass quality.
Feed costs are calculated from feed intake of young replacement stock and feed intake of lactating cows. Feed intake of young replacement stock is based on energy requirements for maintenance and growth. It is assumed, that 90% of the energy requirement is supplied by roughage and 10% by concentrate. Feed intake of lactating cows is calculated monthly and is based on energy requirement and dry-matter intake capacity. Energy requirement of lactating cows is a function of live weight (maintenance), milk production, body tissue mobilization and restoration, age-dependent growth and pregnancy. Dry-matter intake capacity is defined in terms of dry-matter intake of a reference feed and is a function of live weight, milk production and month in lactation. By means of 'fill values' it is defined to what extent intake of a kilogram dry-matter of concentrate or roughage takes up dry-matter intake capacity of reference feed. From the ratio between energy requirement and dry-matter intake capacity, in relation to the quality of offered concentrate and roughage (energy content and fill value), composition of feed intake of lactating cows is derived. Therein, concentrate intake is minimized in order to minimize feed costs.
Labour costs and other variable costs include all costs which are a (linear) function of numbers of cows at the farm. It is assumed that these costs are independent of levels of genetic merit of milk and beef production traits.
Parameters of the model represent the Dutch Black and White population. Prices represent average levels in The Netherlands for the period 1985 - 1986.

According to the definition of economic values given, equation (3) is derived from equations (1) and (2). This paper is restricted to studying influences of production circumstances on economic values in situations without output limitations. Size of the farm is established by a limited number of cows. Equation (3) is the general formula used for calculation of economic values assuming a limited number of cows. As equation (3) shows, for this perspective economic values originate from marginal changes in milk production, beef production and feed costs per cow.

$$\text{economic value} = p_{mib}\delta MICC + p_{mif}\delta MIFC + p_{mip}\delta MIPC + p_{bec}\delta BECC +$$

$$p_{bed}\delta BEDC - p_c\delta CC - p_{rm}\delta RMC \qquad (Dfl.unit^{-1}.cow^{-1}.year^{-1}) \qquad (3)$$

in which $\delta$ symbolizes the marginal change from the basic situation to the situation after marginal change in genetic merit of a single trait.

Production traits considered within this study are the given starting points in simulating milk production and live weight:

- milk production traits of a first-parity cow in 305-day lactation, age at calving is 24 months:
  - carrier (milk without fat and protein);
  - fat;
  - protein;
- beef production traits:
  - birth weight of a female calf born as the first calf of a cow;
  - mature live weight of a cow.

Alternative production circumstances studied are: milk production level, levels of birth weight and mature weight, herd composition, quality of roughage and product and production-factor prices. Levels of genetic merit, product and production-factor prices and quality of roughage in the basic situation are summarized in table 1. Alternatives 'milk production' consider different levels of total milk production (carrier + fat + protein) with fat and protein percentages corresponding to the basic situation (4.34% fat and 3.38% protein).

## 3. RESULTS

Results on the influences of production circumstances on the economic values of the considered traits are described in this chapter. Influences are illustrated by giving underlying aspects of quantification and valuation of changes in outputs and inputs.

*Table 1: Levels of variables of the model in the basic situation (Groen, 1988).*

| Studied traits: | abbrevation | level |
|---|---|---|
| milk carrier production[i] (kg) | carrier | 4655. |
| milk fat production[i] (kg) | fat | 219. |
| milk protein production[i] (kg) | protein | 171. |
| birth weight[ii] (kg) | birthw | 36. |
| mature weight[iii] (kg) | maturew | 600. |
| Prices: | | |
| base price of milk ($Dfl.kg^{-1}$) | $p_{mib}$ | - .02 |
| milk fat ($Dfl.kg^{-1}$) | $p_{mif}$ | 9.31 |
| milk protein ($Dfl.kg^{-1}$) | $p_{mip}$ | 11.01 |
| calves[iv] (Dfl.kg live weight$^{-1}$ | $p_{bec}$ | 7.77 |
| disposed animals[v] (Dfl.kg carcass weight$^{-1}$) | $p_{bed}$ | 6.97 |
| roughage market ($Dfl.MJ\ NE_1{}^{-1}$) | $p_{rm}$ | .071 |
| concentrate ($Dfl.MJ\ NE_1{}^{-1}$) | $p_c$ | .072 |
| Roughage quality: | | |
| energy content roughage ($MJ\ NE_1.kg$ dry matter$^{-1}$) | ecr | 6.21 |
| fill value roughage | fvr | 1.10 |

*i : production of a first-parity cow in a 305-day lactation*

*ii : birth weight of a female calf born as the first calf of a cow*

*iii: mature live weight of a cow*

*iv : for a female calf; price of a male calf 4.18 $Dfl.kg^{-1}$ higher*

*v : price of a first-parity cow in the eight month of lactation*

### 3.1. Basic situation

Economic values in the basic situation are given in table 2. As an example, the economic value of fat is worked out. Increase in genetic merit for fat production will result in an increase in fat output, an increase in dry-matter intake capacity and an increase in energy requirement per average present lactating cow. Genetic merit for fat production is defined on a first-parity cow base. The model calculates, that an increase in genetic merit for fat by 1 unit (1 kilogram per 305-days lactation) results in an increase of 1.19 kilogram fat per average present lactating cow. The main reason for this higher output is the higher production of second-parity and

*Table 2: Economic values in relation to production levels ($Dfl.unit^{-1}.cow^{-1}.year^{-1}$).*

| | trait | | | | |
|---|---|---|---|---|---|
| alternative | carrier[i] | fat[i] | protein[i] | birthw[ii] | maturew[ii] |
| basic | - .13 | 7.97 | 11.27 | 7.35 | - .92 |
| milk | | | | | |
| - 20% | - .12 | 8.05 | 11.32 | 7.37 | - .93 |
| + 20% | - .13 | 7.91 | 11.23 | 7.34 | - .92 |
| birthw | | | | | |
| - 20% | - .13 | 7.97 | 11.27 | 7.26 | - .92 |
| + 20% | - .13 | 7.97 | 11.27 | 7.42 | - .93 |
| maturew | | | | | |
| - 20% | - .13 | 7.97 | 11.27 | 7.39 | - 1.01 |
| + 20% | - .13 | 7.98 | 11.28 | 7.31 | - .87 |

*i : unit = $kg.lactation^{-1}$*

*ii: unit = kg*

older cows relative to first-parity cows. Changes in production of carrier, protein, new-born calves and disposed animals (equation (3)) are zero when increasing genetic merit for fat production. Increase in dry-matter intake capacity is small relative to the increase in energy requirement. Therefore, the ratio between energy requirement and dry-matter intake capacity increases and the composition of feed intake is forced to a higher energy density per kilogram dry-matter intake. Marginal energy requirement per 1.19 kilogram fat equals 43.0 MJ $NE_1.cow^{-1}.year^{-1}$: intake of concentrate is increased by 46.3 MJ $NE_1$ and intake of roughage is decreased by 3.3 MJ $NE_1$ (table 3). Taking into account production-factor and product prices given in table 1, the economic value of fat equals:

$1.19 * 9.31 - 46.3 * .072 + 3.3 * .071 = 7.97\ Dfl.unit^{-1}.cow^{-1}.year^{-1}$.

In the basic situation, increasing carrier and protein production also increase the ratio between energy requirement and dry-matter intake capacity. Increasing live weight decreases this ratio, giving rise to a lower energy density of the diet.

The economic value of mature weight originates from an increased energy requirement for raising female stock, increased energy requirements for

*Table 3: Marginal energy requirement per unit of change in genetic merit*[i] *in dependence on production levels (MJ $NE_l$.$cow^{-1}$.$year^{-1}$).*

| | | marginal energy requirement | |
|---|---|---|---|
| alternative trait | total | concentrate | roughage |
| **basic** | | | |
| carrier | + 1.4 | + 1.4 | - .0 |
| fat | + 43.0 | + 46.3 | - 3.3 |
| protein | + 27.8 | + 30.4 | - 2.6 |
| birthw | + .2 | - 9.7 | + 9.9 |
| maturew | + 18.3 | - 26.1 | + 44.4 |
| **milk + 20%** | | | |
| carrier | + 1.4 | + 1.4 | + .0 |
| fat | + 43.7 | + 59.0 | - 15.3 |
| protein | + 28.2 | + 36.9 | - 8.7 |
| birthw | + .2 | - 4.9 | + 5.1 |
| maturew | + 18.3 | - 28.8 | + 47.1 |
| **maturew + 20%** | | | |
| carrier | + 1.4 | + 2.4 | - 1.0 |
| fat | + 43.1 | + 35.2 | + 7.9 |
| protein | + 27.9 | + 23.0 | + 4.9 |
| birthw | + .1 | + .0 | + .1 |
| maturew | + 17.5 | - 15.1 | + 32.6 |

*i: excluding marginal requirements for young replacement stock*

lactating cows, and increased selling of kilograms disposed young female stock and lactating cows.

### 3.2. Alternative production levels

Economic values for alternatives considering different production levels are summarized in table 2. Economic values of milk and beef production traits are quite insensitive to changes in production levels. Influences on marginal incomes are negligible. Influences of production levels on total marginal energy intake are small (table 3); higher production levels give rise to slightly higher marginal feed requirements for milk production. The

*Table 4: Economic values ($Dfl.unit^{-1}.cow^{-1}.year^{-1}$), product output levels ($kg.cow^{-1}.year^{-1}$) and levels of marginal production per unit of change in genetic merit for herd composition alternatives LOW and HIGH[i].*

| trait | economic values LOW | economic values HIGH | product output level LOW | product output level HIGH | change in product output LOW | change in product output HIGH |
|---|---|---|---|---|---|---|
| carrier | - .13 | - .13 | 6017.6 | 6007.1 | 1.20 | 1.20 |
| fat | 7.96 | 8.00 | 280.2 | 279.9 | 1.19 | 1.19 |
| protein | 11.26 | 11.30 | 221.8 | 221.4 | 1.21 | 1.21 |
| birthw | 7.97 | 7.28 | 35.2 | 32.4 | .78 | .73 |
| maturew | - .94 | - .87 | 142.1 | 179.3 | .25 | .31 |

*i: alternatives LOW and HIGH refer to optimum replacement policies when facing lowered and raised prices per kilogram carcass of disposed animals, respectively.*

ratio in which marginal energy intake is supplied by roughage and concentrate is greatly influenced by the production level. However, given the small price difference between roughage energy and concentrate energy in the basic situation (.001 $Dfl.MJ\ NE_1^{-1}$; table 1), these differences in energy supply do not result in large influences of production levels on economic values.

### 3.3. Alternatives herd composition

Influences of alternative herd compositions on economic values are calculated, and results are given in table 4. Alternatives 'LOW' and 'HIGH' refer to optimum replacement policies when facing lowered and raised prices per kilogram carcass of disposed animals, respectively (Van Arendonk, 1985). Average herd life of cows for alternatives HIGH and LOW are 36.1 and 46.0 months, respectively. Table 4 shows, that influences of herd composition on economic values of milk production traits are small. However, influences on economic values of birth weight and mature weight are noteworthy.

*Table 5: Marginal energy requirement per unit of change in genetic merit[i] in relation to roughage quality (MJ $NE_l.cow^{-1}.year^{-1}$).*

| alternative | trait | marginal energy requirement total | concentrate | roughage |
|---|---|---|---|---|
| fvr[ii] + 10% | | | | |
| | carrier | + 1.4 | + .9 | + .5 |
| | fat | + 43.0 | + 50.4 | - 7.4 |
| | protein | + 27.8 | + 32.5 | - 4.7 |
| | birthw | + .2 | - 4.8 | + 5.0 |
| | maturew | + 18.3 | - 20.9 | + 39.2 |
| ecr[ii] - 10% | | | | |
| | carrier | + 1.4 | + 1.1 | + .3 |
| | fat | + 43.0 | + 49.5 | - 6.5 |
| | protein | + 27.8 | + 33.4 | - 5.6 |
| | birthw | + .2 | + .0 | + .2 |
| | maturew | + 18.3 | - 20.7 | + 39.0 |

*i : excluding requirements for young replacement stock*

*ii: fvr = fill value roughage; ecr = energy content roughage (table 1)*

Differences between economic values for alternative herd compositions can be explained by differences in marginal levels of changes in outputs (table 4).

Increasing % male calves from 50% (basic) to 70% changes the economic value of birth weight from 7.35 to 8.29 $Dfl.kg^{-1}.cow^{-1}.year^{-1}$. Decreasing % calves born alive from 95% (basic) to 90%, decreases the economic value of birth weight to 6.79 $Dfl.kg^{-1}.cow^{-1}.year^{-1}$. Influences of sex ratio and percentage calves born alive originate from changes in marginal levels of outputs of new-born calves per cow improving genetic merit for birth weight. Both alternatives do not change economic values of other considered traits.

Use of beef bulls for terminal crossing not only influences quantitative levels of marginal outputs of new-born calves, but also the value of marginal outputs. Only one half of the change in genetic merit for birth weight in the dairy breed will be expressed in cross-bred calves. But the value of this half is the price of pure-bred calves plus the price bonus for cross-bred calves (2.00 $Dfl.kg^{-1}$; Groen, 1988). It is assumed, that 38% of the cows are inseminated with semen of beef bulls. This percentage equals percentage of female calves not needed for replacement. The economic value of birth weight for the alternative considering terminal beef crossing equals 5.52 $Dfl.kg^{-1}.cow^{-1}.year^{-1}$ (- 25%).

### 3.4. Alternative roughage qualities

Quality of roughage is described by energy content and fill value. Table 5 shows, that both energy content and fill value of roughage influence marginal intake requirements for roughage and concentrate when increasing levels of genetic merit. Table 6 shows the differences in economic values for the alternative roughage qualities, considering different price situations. It can be concluded, that influences of roughage quality on economic values of milk and beef production traits are limited.

### 3.5. Alternative price elements

Table 7 gives economic values of milk and beef production traits in relation to product prices. Changes in product prices will only change economic values of those traits that influence output levels of corresponding products. Therefore, the influences of product price changes on economic values are rather specific.

Figure 1 shows influences of prices of concentrate and roughage on economic values. Figure 1a shows the effect of different concentrate prices with constant roughage price and figure 1b vice versa. For figure 1c both concentrate and roughage prices are changed simultaneously, with a constant price difference between concentrate and roughage. The price of concentrate influences the economic values of both milk and beef production traits. Economic values of milk are hardly influenced by price of roughage. A simultaneous increase of both feed prices decreases economic values of milk and beef production traits. A high concentrate price favours the economic values of beef production traits; a high roughage price favours the economic values of milk production traits. Considering only milk production traits,

*Table 6: Economic values of production traits in relation to roughage quality (Dfl.unit$^{-1}$.cow$^{-1}$.year$^{-1}$).*

| | trait | | | | |
|---|---|---|---|---|---|
| alternative | carrier | fat | protein | birthw | maturew |
| basic | - .13 | 7.97 | 11.27 | 7.35 | - .92 |
| --- ecr | | | | | |
| - 10% | - .13 | 7.96 | 11.27 | 7.34 | - .93 |
| + 10% | - .13 | 7.99 | 11.29 | 7.35 | - .94 |
| --- fvr | | | | | |
| - 10% | - .12 | 8.00 | 11.29 | 7.35 | - .94 |
| + 10% | - .13 | 7.96 | 11.27 | 7.35 | - .93 |
| $p_{rm}$ - 10% | | | | | |
| ecr | | | | | |
| - 10% | - .12 | 7.92 | 11.23 | 7.43 | - .59 |
| + 10% | - .12 | 8.10 | 11.37 | 7.53 | - .66 |
| fvr | | | | | |
| - 10% | - .12 | 8.15 | 11.39 | 7.47 | - .69 |
| + 10% | - .12 | 7.91 | 11.23 | 7.47 | - .59 |

a high concentrate price favours the economic value of protein. Figures in table 3 show, that the total marginal energy requirements per unit change in genetic merit for birth weight and mature weight are small relative to the exchange in energy intake from concentrate to roughage. This does not hold for the milk production traits. Therefore, economic values of beef production traits are rather sensitive to the price difference between roughage and concentrate. This is expressed in increasing economic values of birth weight and mature weight with increasing price of concentrate (figure 1a). Also, the larger decrease in economic value when increasing roughage price (figure 1b), relative to the decrease when increasing both concentrate and roughage prices (figure 1c), can be explained by the influence of the price difference between roughage and concentrate.

*Table 7: Economic values of production traits in relation to product prices (Dfl.unit$^{-1}$.cow$^{-1}$.year$^{-1}$).*

| alternative | trait | deviation | | | | |
|---|---|---|---|---|---|---|
| | | - 20% | - 10% | basic | + 10% | + 20% |
| $p_{mif}$ | | | | | | |
| | fat | 5.74 | 6.86 | 7.97 | 9.08 | 10.20 |
| $p_{mip}$ | | | | | | |
| | protein | 8.61 | 9.94 | 11.27 | 12.60 | 13.94 |
| $p_{mib}$, $p_{mif}$, $p_{mip}$ | | | | | | |
| | carrier | - .12 | - .12 | - .13 | - .13 | - .13 |
| | fat | 5.74 | 6.86 | 7.97 | 9.07 | 10.19 |
| | protein | 8.61 | 9.94 | 11.27 | 12.60 | 13.93 |
| $p_{bec}$ | | | | | | |
| | birthw | 6.16 | 6.75 | 7.35 | 7.95 | 8.54 |
| $p_{bed}$ | | | | | | |
| | maturew | - 1.10 | - 1.01 | - .92 | - .83 | - .74 |

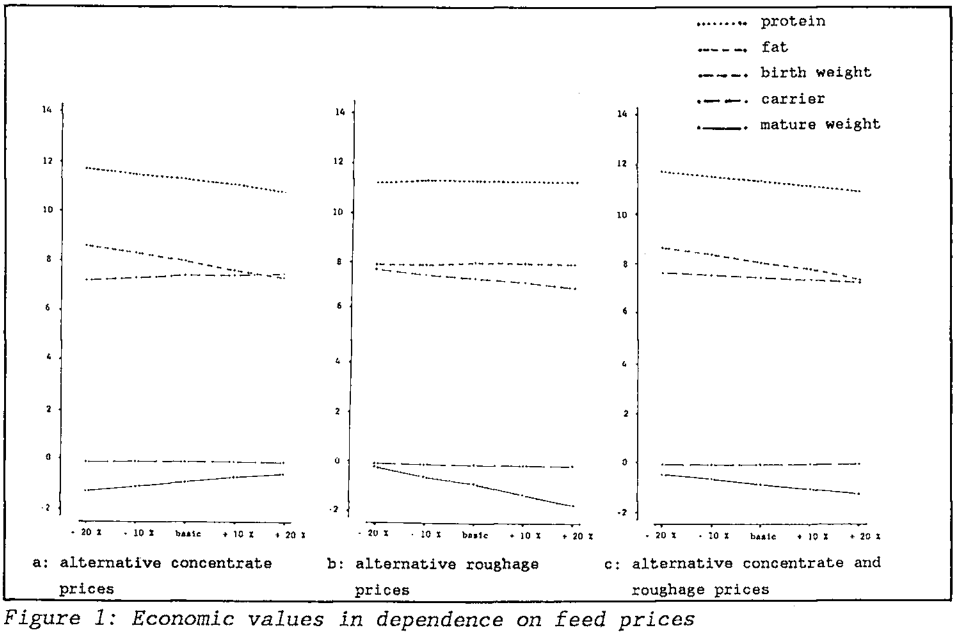


*Figure 1: Economic values in dependence on feed prices (Dfl.unit$^{-1}$.cow$^{-1}$.year$^{-1}$).*

## 4. DISCUSSION AND CONCLUSIONS

Within this study economic values are derived on the basis of a fixed number of animals and assuming a profit interest of selection. Within this study, conditions supposed by Smith et al. (1986) are not applied. Considering fixed costs (with respect to size of the enterprise) to be variable per unit of product, as proposed by Smith et al. (1986) requires assumptions on (optimum) size of the enterprise. If one assumes that changes in number of animals (given a limited output) is accomplished by number of enterprises (all having the same size) and not by number of animals within an enterprise, methods are comparable. However, structure of industry is assumed to be fixed. Structural developments within industry are detached from improvements in efficiency of production. Therefore, the condition of regarding fixed costs as variable costs may be inappropriate. Groen (1989) studied the influences of imposition of limitations (rescaling condition proposed by Smith et al. (1986)). Applicability of the rescaling condition is discussed in that paper.

Taking into account differences in price level assumptions, economic values of milk production traits correspond well to figures presented by Van Arendonk et al. (1985) and Wilmink and De Graaf (1986). Sensitivity of economic values of milk production traits is almost restricted to milk product prices and price of concentrate. Economic values of milk production traits show only a very small non-linearity. This non-linearity is related to a non-linear increase in energy requirement for marginal milk production. The small price difference between concentrate and roughage and an independence of non-feed costs and milk production level restrain non-linearity of the economic values of milk production traits.

Beef production traits might be split up in two groups: those related to new-born calves and those related to disposed adult cows. Birth weight and mature weight are considered to be representatives for the first and second group, respectively. Economic values of beef production traits are sensitive to herd composition, beef product prices and prices of concentrate and roughage.

Results from this study indicate, that herd composition influences product output levels of new-born calves and adult cows (corresponding to results of Weber, 1976). In other words, the replacement policy is a tool to change product output levels of new-born calves and adult cows. The optimum replacement policy of the farmer is affected by the relative levels of rearing costs (including salvage value of the newborn calf) and carcass values of disposed adult cows (Van Arendonk, 1985). This means, that via optimization of the replacement policy, prices might have indirect influences on economic values of beef production traits.

Implementation of (bio-)technology to increase number of calves per cow per year (e.g. twining) and to increase percentage of male calves (e.g. sperm or embryo sexing), can be used to maintain or even increase quality and quantity of beef production from dairy (or dual purpose) breeds (Cunningham, 1975). Economic values of birth weight for alternatives considering influences of sex ratio and percentages calves born alive indicate, that application of these technologies will not lead to a decrease in economic importance of improvement of beef production traits for the dairy breed. Due to the extra benefit (price bonus) of cross-bred calves, use of terminal beef crossing will lead to changes in economic values of beef production traits. If we assume cross-bred calves to express 50% of the improvement in genetic merit for the dairy breed, and the price bonus to be less than 100% of the price of pure-bred dairy calves, then terminal crossing will lead to a decrease in economic importance of beef production traits for dairy cattle breeding. It has to be studied to what extent combination of new reproduction techniques and beef crossing influences breeding goals.

Morris and Wilton (1977) suggested that the economic value of cow size should be calculated according to Hazel's definition (Hazel, 1943), in order to determine the importance of cow size to economic efficiency at the farm level. According to Morris and Wilton (1977), this calculation should include modelling of the rearing period. The calculation method used in this study (Groen, 1988) copes with the suggestions made by Morris and Wilton (1977). From the results, it appears, that the change in economic efficiency when increasing mature weight is small, but negative. It has to be emphasized, that the economic value of mature weight is calculated assuming no changes in body composition.

An additional alternative is performed to estimate the bias of an exclusion of the rearing period. Ignoring rearing costs and marginal returns from disposed young replacement stock causes a large over-estimation of the economic value of birth weight (- 34%). Only a little bias for the economic value of mature weight is found (- 1%). Morris and Wilton (1977) concluded from their review of literature, that the relationship between cow size and economic efficiency of dairy production depends on the feeding regime involved. Results of this study indicate, that such a relationship, when feeding to intake capacity and energy requirement, will only exist if significant price differences between different feed components are assumed.

In conclusion, in situations without output limitations at the farm level, prices are of decisive importance in defining the relative economic importance of selection on milk and beef production traits. Prices of milk products and beef products influence only the economic values of milk and beef production traits, respectively. High concentrate prices increase the economic values of beef production traits relative to milk production traits. Also, a large difference between the price of roughage and the price of concentrate favours selection for beef production traits. The influence of prices originate from: 1. direct influences on values of marginal inputs and outputs; 2. indirect influences on quantitaties of marginal inputs and outputs via optimization of farm management. The second point is mainly expressed in the influences of herd composition on the economic values of birth weight and mature weight.
Variation in production circumstances might ask for diversification of breeding goals (Smith, 1985, 1986). Considering breeding goals with milk production traits, a diversification could be based on variation in milk prices and price of concentrate. Considering milk and beef production traits, variation in beef prices and price of roughage could also be taken into account. Conclusions regarding necessity of diversification of breeding goals cannot be drawn directly from sensitivity of economic values. Additional studies have to determine to what extent sensitivity of economic values towards production circumstances influences revenues of cattle breeding programmes. As a sequel to this study, the sensitivity of economic values in situations with limitations has to be studied.

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Chapter four

# Economic values in cattle breeding. II. Influences of production circumstances in situations with output limitations.

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ABSTRACT

This study discusses sensitivity of economic values of milk and beef production traits in cattle breeding to imposition of limitations at the farm level and to production circumstances in situations with limitations. Economic values are calculated in situations without limitations, with milk output limitations, with roughage input limitations and with simple product output limitations.

The imposition of milk output limitations results in a decrease in economic value of carrier (milk without fat and protein). The imposition of roughage input limitations mainly causes a decrease in economic values of beef production traits relative to the economic values of milk production traits. Simple product output limitations strongly influence relative economic values of production traits. In situations with limitations, economic values are sensitive to product and production-factor prices, milk production level and level of mature weight.

## 1. INTRODUCTION

The introduction of the quota system for milk production in the European Community in 1984 has, in several countries, resulted in imposition of product output limitations at the farm level. Also in countries other than E.C. members, such as Norway and Canada, output limitations at the farm level were imposed in order to match milk production to milk consumption. A milk output limitation is a practical example of a limitation at the farm level. Less commonly, but nevertheless of practical and theoretical importance, are output limitations on other products or input limitations on production-factors.

Literature shows evidence, that imposition of limitations influences economic values of animal traits in cattle breeding. In situations with milk output limitations, relative economic values of improvement of genetic merit of different traits are changed (Van Arendonk et al., 1985; Zeddies, 1985). Moreover, imposition of limitations may increase influences of production circumstances on economic values of production traits. In situations without limitations, sensitivity of economic values of milk production traits is almost limited to milk product prices and price of concentrates (Groen, 1989). However, Van Arendonk et al. (1985) found economic values of milk production traits in situations of milk output limitations to be sensitive to milk production level, prices of new-born calves and adult cows, and price of roughages.

Accurate calculation of economic values in relation to production circumstances is necessary. Large changes in economic values may reduce efficiency of improvement of animal production (Smith, 1983). Thereby, influences of production circumstances on economic values may lead to a diversification of the breeding goal (Smith, 1985, 1986). Knowledge on the influences of limitations on the economic values of milk and beef production traits is limited and needs to be extended in terms of other traits, other limitations and other production circumstances.

The aim of this study is to determine the sensitivity of economic values of milk and beef production traits in cattle breeding to:

1. the imposition of limitations at farm level; and
2. different production circumstances in situations with limitations.

Economic values are calculated in situations without limitations, with milk output limitations, with roughage input limitations and with output limitations on simple products. Sensitivity of economic values in situations without limitations is discussed by Groen (1989).

## 2. METHOD

The economic value of a trait is defined as 'the change in profit of the farm expressed per average present lactating cow per year, as a consequence of one unit of change in genetic merit of the trait considered'. Modelling at the farm level is thought to give good insight into the sensitivity of economic values towards production circumstances at animal, herd, farm and higher levels. Choice of the interest of selection, profit (= outputs - inputs) maximization, corresponds to the general interest of individual farms. The term 'unit' will have to be detailed per trait (e.g. kilogram per lactation when considering milk production traits). In calculating economic values, genetic merit of the trait considered is to be changed without changing levels of any other trait.

The dairy farm model described by Groen (1988) is used to calculate economic values of milk and beef production traits. A description of the principles of the model and inputs and outputs equations is given by Groen (1989). This paper studies influences of production circumstances on economic values in situations with input or output limitations at the farm level. This implies, that size of the farm is established by size of the input or output quota. When considering input or output limitations, change in input requirements or product output per cow for the limited input or output component will result in a change in number of cows. Smith et al. (1986) used the term 'rescaling' to denote the change in number of animals at the farm. Equation (1) is the general equation for calculating economic values in situations with input or output limitations. Equation (1) is derived from the farm input and output equations given by Groen (1989).

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$$\text{economic value} = p_{mib}\delta MICC + p_{mif}\delta MIFC + p_{mip}\delta MIPC + p_{bec}\delta BECC + p_{bed}\delta BEDC - p_{c}\delta CC - p_{rm}\delta RMC + \delta N/N_1 * [p_{mib}MICC_2 + p_{mif}MIFC_2 + p_{mip}MIPC_2 + p_{bec}BECC_2 + p_{bed}BEDC_2 - p_{c}CC_2 - p_{rm}RMC_2 - p_{l}LRC - VCC]$$

$(Dfl.unit^{-1}.cow^{-1}.year^{-1})$ (1)

in which:

- N : number of average present lactating cows,
- MICC : milk carrier production level $(kg.cow^{-1}.year^{-1})$,
- $p_{mib}$ : base price of milk $(Dfl.kg^{-1})$,
- MIFC : milk fat production level $(kg.cow^{-1}.year^{-1})$,
- $p_{mif}$ : milk fat price $(Dfl.kg^{-1})$,
- MIPC : milk protein production level $(kg.cow^{-1}.year^{-1})$,
- $p_{mip}$ : milk protein price $(Dfl.kg^{-1})$,
- BECC : beef production new-born calves $(kg.cow^{-1}.year^{-1})$,
- $p_{bec}$ : weighed price of new-born calves $(Dfl.kg^{-1})$,
- BEDC : beef production disposed animals $(kg.cow^{-1}.year^{-1})$,
- $p_{bed}$ : weighed price of disposed cows $(Dfl.kg^{-1})$,
- CC : concentrate requirements $(MJ\ NE_1.cow^{-1}.year^{-1})$,
- $p_c$ : price of concentrate $(Dfl.MJ\ NE_1^{-1})$,
- RMC : amount of purchased roughage $(MJ\ NE_1.cow^{-1}.year^{-1})$,

$p_{rm}$ : price of roughage on the market (Dfl.MJ $NE_1^{-1}$),
RF : amount of roughage grown on the farm (MJ $NE_1$.$year^{-1}$),
$p_{rf}$ : costs of roughage grown on the farm (Dfl.MJ $NE_1^{-1}$),
LRC : labour attracted from the market ($hour.cow^{-1}.year^{-1}$),
$p_{lm}$ : price of labour on the market ($Dfl.hour^{-1}$),
LF : amount of labour supplied by the farmer ($hour.year^{-1}$),
$p_{lf}$ : price of labour supplied by the farmer ($Dfl.hour^{-1}$),
VCC : other variable cost ($Dfl.cow^{-1}.year^{-1}$),
Subscripts 1 and 2 refer to the basic situation and situation after marginal change of genetic merit, respectively,
$\delta$ symbolizes the marginal change between situations 1 and 2.

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Equation (1) shows that, within the perspective considered, economic values originate from marginal changes in milk production, beef production and feed costs per cow, and from marginal changes in number of cows. Marginal change in number of cows is multiplied by the margin between revenues and variable costs per cow. The change in number of cows, expressed per present animal before improvement of genetic merit, equals the change in production level P (or level of input) per cow per unit of P after improvement of genetic merit (equation (2)).

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$$N_2 * P_2 = P_1 * N_1 \iff \delta N/N_1 = - \delta P/P_2 \qquad (2)$$

in which further:
P : production level or level of inputs ($units.cow^{-1}.year^{-1}$).

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Improvement of genetic merit causing the level of inputs of a production-factor to decrease, may lead to an increase in number of animals at the farm. In situations without limitations, economic values are calculated on base of a limited number of cows at the farm ($\delta N = 0$).
Production traits considered within this study are:
- milk production traits first-parity cow in 305-day lactation, age at calving is 24 months:
  - carrier (milk without fat and protein);
  - fat;

  - protein;
- beef production traits (parameters simulation of live weight by use of the Von Bertalanffy curve):
  - birth weight of a female calf born as the first calf of a cow;
  - mature live weight of a cow.

Economic values are calculated in situations without limitations, with milk output limitations, with roughage input limitations and with simple product output limitations at farm level. Considering simple output limitations, economic values are calculated as follows:

- economic value carrier considering a carrier output limitation;
- economic value fat considering a fat output limitation;
- economic value protein considering a protein output limitation;
- economic value birth weight considering an output limitation on kilograms of new-born calf equivalent;
- economic value mature weight considering an output limitation on kilograms disposed cow equivalent.

From equations (1) and (2), equations for the calculation of specific economic values for a trait, given a limitation, are derived. As an example, equations for calculation of the economic value of fat in situations with milk output limitations, with roughage input limitations and with a simple product output limitation on fat are presented. Marginal production of carrier, protein, new-born calf equivalent and disposed cow equivalent per cow are zero when increasing genetic merit for fat production. In situations with milk output limitation, roughage input limitation and fat output limitation, P (equation (2)) equals milk production level (MICC + MIFC + MIPC), level of roughage purchased (RMC) and fat production level (MIFC), respectively.

---

$$\text{economic value fat 'milk output limitation'} = p_{mif}\delta MIFC - p_c\delta CC - p_{rm}\delta RMC$$
$$- \delta MIFC * [p_{mib}MICC_2 + p_{mif}MIFC_2 + p_{mip}MIPC_2 + p_{bec}BECC_2 + p_{bed}BEDC_2$$
$$- p_cCC_2 - p_{rm}RMC_2 - p_lLRC - VCC]/(MICC_2 + MIFC_2 + MIPC_2) \qquad (3)$$

---

$$\text{economic value fat 'roughage input limitation'} = p_{mif}\delta MIFC - p_c\delta CC$$

$$- \delta RMC * [p_{mib}MICC_2 + p_{mif}MIFC_2 + p_{mip}MIPC_2 + p_{bec}BECC_2 + p_{bed}BEDC_2$$

$$- p_cCC_2 - p_lLRC - VCC]/RMC_2 \qquad (4)$$

$$\text{economic value fat 'fat output limitation'} = - p_c\delta CC - p_{rm}\delta RMC$$

$$- \delta MIFC * [p_{mib}MICC_2 + p_{mip}MIPC_2 + p_{bec}BECC_2 + p_{bed}BEDC_2 - p_cCC_2$$

$$- p_{rm}RMC_2 - p_lLRC - VCC]/MIFC_2 \qquad (5)$$

Each alternative for which economic values are calculated is named according to the limitation imposed and production circumstances that are varied from the basic situation. Alternatives 'milk production level' consider different levels of total milk production (carrier + fat + protein) with fat and protein percentages corresponding to the basic situation (4.34% fat and 3.38% protein). For the basic situation, it is assumed, that there is a surplus in supply of labour by the farmer. In order to account for the fact that saved labour can only partly be used in other production sectors, market price of labour is set equal to a low price of 12.50 $Dfl.hour^{-1}$. The alternative 'labour' considers a labour price of 25.00 $Dfl.hour^{-1}$. Values of variables of the model in the basic situation are given in table 1.

## 3. RESULTS

The first paragraph deals with influences of limitations at the farm level on economic values within the basic situation. The second paragraph deals with influences of production circumstances in situations with limitations.

### 3.1. Influences of limitations

Table 2 shows economic values of milk and beef production traits in

*Table 1: Levels of variables of the model in the basic situation (Groen, 1988).*

| Studied traits: | abbreviation | level |
|---|---|---|
| carrier production[i] (kg) | carrier | 4655. |
| milk fat production[i] (kg) | fat | 219. |
| milk protein production[i] (kg) | protein | 171. |
| birth weight[ii] (kg) | birthw | 36. |
| mature weight[iii] (kg) | maturew | 600. |
| Prices: | | |
| base price of milk ($Dfl.kg^{-1}$) | $p_{mib}$ | - .02 |
| milk fat ($Dfl.kg^{-1}$) | $p_{mif}$ | 9.31 |
| milk protein ($Dfl.kg^{-1}$) | $p_{mip}$ | 11.01 |
| calves[iv] (Dfl.kg live $weight^{-1}$) | $p_{bec}$ | 7.77 |
| disposed cows[v] (Dfl.kg carcass $weight^{-1}$) | $p_{bed}$ | 6.97 |
| roughage market (Dfl.MJ $NE_1^{-1}$) | $p_{rm}$ | .071 |
| concentrate (Dfl.MJ $NE_1^{-1}$) | $p_c$ | .072 |
| labour ($Dfl.hour^{-1}$) | $p_{lm}$ | 12.50 |
| Roughage quality: | | |
| energy content roughage (MJ $NE_1$.kg dry $matter^{-1}$) | ecr | 6.21 |
| fill value roughage | fvr | 1.10 |

*i : production of a first-parity cow in a 305-day lactation*

*ii : birth weight of a female calf born as the first calf of a cow*

*iii: mature live weight of a cow*

*iv : for a female calf; price of a male calf 4.18 $Dfl.kg^{-1}$ higher*

*v : basis price of a first-calf cow in the eight month of lactation*

situations without limitations, with milk output limitations, with roughage input limitations and with simple product output limitations.

Milk output limitations reduce economic values of carrier, fat and protein by about .20 $Dfl.unit^{-1}.cow^{-1}.year^{-1}$ (154%, 3% and 2%, respectively). Thereby, relative importances of milk production traits change. Absolute economic values of beef production traits are not influenced by imposition of milk output limitations. Figures presented can be used to calculate economic values of milk. Assuming fat and protein percentages to be 4.2% and 3.4%, respectively, economic value of milk equals .60 $Dfl.unit^{-1}.cow^{-1}.year^{-1}$ in the basic situation. In situations with milk output limitations,

*Table 2: Economic values of milk and beef production traits in relation to limitations imposed ($Dfl.unit^{-1}.cow^{-1}.year^{-1}$).*

| | trait | | | | |
|---|---|---|---|---|---|
| limitation | carrier | fat | protein | birthw | maturew |
| no | - .13 | 7.97 | 11.27 | 7.35 | - .92 |
| milk | - .33 | 7.75 | 11.04 | 7.35 | - .92 |
| roughage | - .13 | 8.09 | 11.37 | 6.58 | - 2.62 |
| simple | - .35 | 3.04 | 4.86 | - 17.73 | - 2.82 |

economic value of milk reduces by 33% to .40 $Dfl.unit^{-1}.cow^{-1}.year^{-1}$. Roughage input limitations decrease economic values of beef production traits relative to economic values of milk production traits. Economic value of carrier is not influenced by imposition of roughage input limitations. Economic values of fat and protein increase by 2% and 1%, respectively. Economic values of birth and mature weight decrease by 10% and 185%, respectively.

Simple output limitations decrease drastically the economic values of both milk and beef production traits. Economic values of carrier, fat and protein decrease by 169%, 62% and 57%, respectively. Economic values of birth and mature weight decrease by 341% and 207%, respectively. These results indicate, that simple product output limitations strongly influence relative economic values of production traits.

## 3.2. Influences of production circumstances

Table 3 gives economic values of milk and beef production traits in situations with milk output limitations, in relation to production circumstances. Economic values of milk production traits are mainly influenced by milk prices ($p_{mib}$, $p_{mif}$, $p_{mip}$) and price of concentrate ($p_c$). High milk prices and low price of concentrate give rise to high economic values for fat and protein. Within the alternative 'price concentrate - 20%' economic values of fat and protein in situations with milk output limitations equal 8.39 and 11.45 $Dfl.unit^{-1}.cow^{-1}.year^{-1}$, respectively. An increase in price of concentrate to 120% of the level within the basic

*Table 3: Economic values of milk and beef production traits in situations with milk output limitations in relation to production levels and product and production-factor prices (Dfl.unit$^{-1}$.cow$^{-1}$.year$^{-1}$).*

| | trait | | | | |
|---|---|---|---|---|---|
| alternative | carrier | fat | protein | birthw | maturew |
| basic | - .33 | 7.75 | 11.04 | 7.35 | - .92 |
| milk | | | | | |
| - 20% | - .23 | 7.92 | 11.19 | 7.37 | - .93 |
| + 20% | - .40 | 7.62 | 10.94 | 7.34 | - .92 |
| birthw | | | | | |
| - 20% | - .32 | 7.76 | 11.05 | 7.25 | - .92 |
| + 20% | - .34 | 7.73 | 11.03 | 7.42 | - .93 |
| maturew | | | | | |
| - 20% | - .35 | 7.72 | 11.02 | 7.39 | - 1.01 |
| + 20% | - .31 | 7.77 | 11.07 | 7.31 | - .87 |
| $p_{mib}$, $p_{mif}$, $p_{mip}$ | | | | | |
| - 20% | - .15 | 5.71 | 8.57 | 7.35 | - .92 |
| + 20% | - .52 | 9.78 | 13.52 | 7.35 | - .92 |
| $p_{bec}$, $p_{bed}$ | | | | | |
| - 20% | - .30 | 7.77 | 11.07 | 6.11 | - 1.11 |
| + 20% | - .36 | 7.72 | 11.01 | 8.59 | - .73 |
| $p_{rm}$ | | | | | |
| - 20% | - .42 | 7.61 | 10.92 | 7.68 | - .17 |
| + 20% | - .24 | 7.88 | 11.17 | 7.02 | - 1.67 |
| $p_c$ | | | | | |
| - 20% | - .34 | 8.39 | 11.45 | 7.23 | - 1.29 |
| + 20% | - .32 | 7.10 | 10.63 | 7.47 | - .55 |
| $p_{lm}$ | | | | | |
| 25.0[i] | - .27 | 7.81 | 11.10 | 7.35 | - .92 |

*i: Dfl.hour$^{-1}$*

situation decreases economic values of fat and protein to 7.10 and 10.63 Dfl.unit$^{-1}$.cow$^{-1}$.year$^{-1}$, respectively. Since economic values of beef production traits are not influenced by imposition of milk output limitations, sensitivity of economic values equals sensitivity in situations

*Table 4: Economic values of milk and beef production traits in situations with roughages input limitations in relation to production levels and product and production-factor prices ($Dfl.unit^{-1}.cow^{-1}.year^{-1}$).*

| | | | trait | | |
|---|---|---|---|---|---|
| alternative | carrier | fat | protein | birthw | maturew |
| basic | - .13 | 8.09 | 11.37 | 6.58 | - 2.62 |
| milk | | | | | |
| - 20% | - .13 | 7.72 | 11.07 | 6.92 | - 1.42 |
| + 20% | - .12 | 8.79 | 11.74 | 6.37 | - 3.85 |
| birthw | | | | | |
| - 20% | - .10 | 8.08 | 11.29 | 6.41 | - 2.46 |
| + 20% | - .12 | 8.11 | 11.44 | 6.79 | - 2.62 |
| maturew | | | | | |
| - 20% | - .11 | 8.43 | 11.52 | 6.34 | - 3.46 |
| + 20% | - .10 | 7.75 | 11.13 | 6.94 | - 1.88 |
| $p_{mib}$, $p_{mif}$, $p_{mip}$ | | | | | |
| - 20% | - .12 | 5.76 | 8.63 | 7.25 | - 1.12 |
| + 20% | - .13 | 10.41 | 14.11 | 5.92 | - 4.12 |
| $p_{bec}$, $p_{bed}$ | | | | | |
| - 20% | - .13 | 8.07 | 11.35 | 5.46 | - 2.56 |
| + 20% | - .13 | 8.10 | 11.38 | 7.71 | - 2.68 |
| $p_c$ | | | | | |
| - 20% | - .11 | 8.77 | 11.82 | 6.36 | - 3.21 |
| + 20% | - .14 | 7.40 | 10.91 | 6.81 | - 2.03 |
| $p_{lm}$ | | | | | |
| 25.0[i] | - .13 | 8.05 | 11.34 | 6.80 | - 2.12 |

*i: $Dfl.hour^{-1}$*

without limitations. Main elements influencing economic values of beef production traits are: beef prices ($p_{bec}$, $p_{bed}$), the price of roughage and the price of concentrate.

Table 4 gives economic values of milk and beef production traits in situations with roughage input limitations, in relation to production

*Table 5: Economic values of milk and beef production traits in situations with simple product output limitations in relation to production levels and product and production-factor prices ($Dfl.unit^{-1}.cow^{-1}.year^{-1}$).*

| | | | trait | | |
|---|---|---|---|---|---|
| alternative | carrier | fat | protein | birthw | maturew |
| basic | - .35 | 3.04 | 4.86 | - 17.73 | - 2.82 |
| milk | | | | | |
| - 20% | - .24 | 5.32 | 7.68 | - 2.93 | - 1.70 |
| + 20% | - .42 | 1.51 | 2.97 | - 32.37 | - 3.95 |
| birthw | | | | | |
| - 20% | - .34 | 3.26 | 5.14 | - 21.38 | - 2.73 |
| + 20% | - .36 | 2.82 | 4.59 | - 15.12 | - 2.91 |
| maturew | | | | | |
| - 20% | - .37 | 2.57 | 4.27 | - 20.32 | - 3.64 |
| + 20% | - .33 | 3.49 | 5.42 | - 15.34 | - 2.29 |
| $p_{mib}$, $p_{mif}$, $p_{mip}$ | | | | | |
| - 20% | - .15 | 4.94 | 7.44 | 4.09 | - 1.14 |
| + 20% | - .55 | 1.14 | 2.29 | - 39.54 | - 4.50 |
| $p_{bec}$, $p_{bed}$ | | | | | |
| - 20 % | - .32 | 3.70 | 5.69 | - 15.39 | - 2.73 |
| + 20 % | - .38 | 2.39 | 4.04 | - 20.06 | - 2.91 |
| $p_{rm}$ | | | | | |
| - 20 % | - .45 | 1.02 | 2.33 | - 28.10 | - 2.91 |
| + 20% | - .25 | 5.06 | 7.40 | - 7.35 | - 2.73 |
| $p_c$ | | | | | |
| - 20% | - .36 | 3.07 | 4.51 | - 21.15 | - 3.43 |
| + 20% | - .34 | 3.01 | 5.22 | - 14.30 | - 2.21 |
| $p_{lm}^{i}$ | | | | | |
| | - .28 | 4.37 | 6.55 | - 10.51 | - 2.26 |

*i: $Dfl.hour^{-1}$*

circumstances. The main elements influencing economic values of milk production traits are again: milk prices and the price of concentrate. Of less importance are: the milk production level and the level of mature

*Table 6: Economic values of milk and beef productions traits in situations with limitations in relation to herd composition HIGH and LOW*[i] *($Dfl.unit^{-1}.cow^{-1}.year^{-1}$).*

| limit- ation | altern- ative | carrier | fat | trait protein | birthw | maturew |
|---|---|---|---|---|---|---|
| milk | LOW | - .34 | 7.73 | 11.02 | 7.97 | - .94 |
| | HIGH | - .32 | 7.79 | 11.09 | 7.28 | - .87 |
| roughage | LOW | - .12 | 8.09 | 11.37 | 7.20 | - 2.74 |
| | HIGH | - .11 | 8.10 | 11.38 | 6.81 | - 2.46 |
| simple | LOW | - .36 | 2.79 | 4.55 | - 18.05 | - 2.95 |
| products | HIGH | - .34 | 3.33 | 5.23 | - 16.03 | - 2.65 |

*i: alternatives LOW and HIGH refer to optimum replacement policies when facing lowered and raised prices per kilogram carcass of disposed animals, respectively.*

weight (maturew). Economic values of beef production traits are sensitive to all elements, but mainly to: milk and beef product prices, levels of milk production and mature weight and price of concentrate. Low milk prices and milk production level decrease the economic values of milk production traits. In case of roughage input limitations, total costs of roughage become fixed costs. Therefore, changes in cost price of roughage will not influence economic values in situations with roughage input limitations (see equation (4)).

Table 5 gives economic values of milk and beef production traits in situations with simple product output limitations, in relation to production circumstances. All elements influence all economic values. However, a certain order can be distinguished. Economic values of milk production traits are mainly influenced by milk production level, milk prices and price of roughage. Of less importance are mature weight, beef prices and labour price. Note the relative unimportance of price of concentrate. Milk prices, milk production level and price of roughage are the main elements influencing the economic value of birth weight. Milk prices, milk production level, mature weight and price of concentrate are the main elements influencing economic value of mature weight. In general, increase in product prices decreases economic values, while increase in prices of production-factors increases economic values.

Table 6 gives economic values of milk production traits in situations with limitations in relation to herd composition. Alternatives 'LOW' and 'HIGH' refer to optimum replacement policies when facing lowered and raised prices per kilogram carcass of disposed animals (Van Arendonk, 1985). Herd composition appears to have significant influence on absolute economic values of milk and beef production traits. However, compared to influences of other elements, herd composition is relatively unimportant.

Influences of roughage quality on the economic values are not presented within this paragraph, for they are found to be non-significant.

## 4. DISCUSSION AND CONCLUSIONS

This study is focussed on the sensitivity of economic values towards production circumstances. A broad scope of situations is studied (without limitations, input limitations and different output limitations). A comparison of these situations provides information on the way in which different limitations affect estimation of economic values.
The essence of improvement of efficiency of a production system is: saving inputs of production-factors per unit of product and or/a change towards use of cheaper production-factors. This means, that the level of improvement of efficiency (by example given increase in genetic merit of traits) is determined by the amount and the value of saved production factors. The value of saved production-factors corresponds to their actual use. Assuming no limitations in deriving economic values, value of saved production-factors is expressed by their use in the enterprise they are saved from. In situations with limitations, however, saved production-factors cannot be used to increase output of the enterprise. So, the number of animals has to decrease and saved production-factors are valued according to their market price. This way in which limitations affect economic values is demonstrated, firstly, by equation (1) and, secondly, by equation (3), (4) and (5). Equation (1) denotes, that change in number of animals is multiplied by the

margin between revenues and variable costs per cow. When the change in number of animals is zero, equation (1) equals the general equation for calculation of economic values in situations without limitations (Groen, 1989). A large margin between revenues and variable costs corresponds to a high profitability of the enterprise. A high profitability of the enterprise denotes, that the value of production-factors by use in the enterprise greatly exceeds the value of production-factors at the market. Equations (3), (4) and (5) show that change in fat output and concentrate and roughage input per cow ($\delta$MIFC, $\delta$CC and $\delta$RMC, respectively) are, in relation to the limitation considered, multiplied/valued by market price or value within the enterprise.

Imposition of limitations determines the value of saved production-factors. The appropriate situation in deriving economic values should use valuation that corresponds to the interest and production circumstances of the producers. In order to determine this proper situation, economic principles of valuation of saved production-factors within the different situations are to be studied in more detail.

Although within this study fixed costs are not expressed per unit of product (Groen, 1989), situations studied complement to the rescaling approach introduced by Smith <u>et al.</u> (1986). The results of this study show, that in applying the rescaling condition to enterprises with a multiple product output, one should carefully choose the output limitation. Choice of an output limitation definitely influences levels of economic values.

Within this study, limitations only influence economic values of those traits that influence output of the product or input of the production-factor which is limited. This can be explained by:

1. traits are changed independently;
2. within the model, prices are independent (exogeneous) elements.

Milk output limitations reduce economic values of carrier, fat and protein. Reductions correspond closely to figures given by Van Arendonk <u>et al.</u> (1985) and Zeddies (1985). Milk output limitations favour the economic values of fat and protein relative to the economic value of carrier. Milk output limitations also increase the relative economic values of beef production traits.

Increase in genetic merit for fat and protein decrease the amount of roughage needed per cow (Groen, 1989). In situations with roughage input

limitations, saved roughage is used to extend the size of the dairy herd. Increase in genetic merit for birth weight and mature weight increase the amount of roughage needed per cow (Groen, 1989). As a result, imposition of roughage input limitations decreases the economic values of beef production traits relative to the economic values of milk production.
Simple output limitations strongly influence relative economic values of production traits. When we consider all output limitations to occur at the same time, economic values of milk production traits are increased relative to economic values for beef production traits.

From a comparison with results of Groen (1989), it appears that influences of production circumstances on economic values are larger in situations with limitations relative to situations without limitations. This increase in sensitivity can be explained from the introduction of the margin between revenues and variable costs per cow by imposition of limitations. Mainly in situations with specific output limitations, economic values become sensitive to those production circumstances that influence the value of production-factors within the dairy sector: milk prices, price of roughage, milk production level, beef prices and level of mature weight.

Diversification of cattle breeding goals could be based on the occurrence of long-run limitations at farm level. Moreover, a diversification of the goal in cattle breeding in situations with limitations, could be based on differences in prices of products and production-factors and levels of mature weight and milk production of the cows for different groups of farms. Conclusions regarding necessity of diversification of breeding goals cannot be drawn directly from sensitivity of economic values. Additional studies have to determine to what extent sensitivity of economic values towards production circumstances influences revenues of cattle breeding programmes. Within this study, sensitivity of economic values to production circumstances is examinated using standard percentage deviations from the levels within the basic situation, regardless of the real occurring variances in elements. In determining the necessity of a diversification of breeding goals, the real occurring variances in prices and production levels will have to be considered.

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Chapter five

# The economic value of feed intake capacity of dairy cows.

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ABSTRACT

Economic values are important factors in choosing the traits to be included in the breeding goal. In this study, the economic value of feed intake capacity of dairy cows is derived. Influences of production circumstances on the economic value of feed intake capacity are quantified.
The economic value of feed intake capacity is derived assuming that nutrient intake is determined by nutrient requirements: increase in feed intake capacity allows for a cheaper composition of nutrient intake. Feed intake capacity of dairy cows is defined in terms of dry-matter intake capacity of a reference feed and nutrient requirement in terms of energy requirement. The model distinguishes between two feed components: roughage and concentrate. Intake ratios of roughage and concentrate for dairy cows depend on the ratio between energy requirement and dry-matter intake capacity and on the quality of both feed components.
In the basic situation, the economic value of feed intake capacity is equal to 18.55 Dfl.(kg dry-matter.day$^{-1}$)$^{-1}$.cow$^{-1}$.year$^{-1}$. The economic value is highly sensitive to feed and animal factors influencing feed intake of dairy cows, and to the difference between concentrate and roughage price. This sensitivity requires a consideration of production circumstances in defining breeding goals including feed intake capacity.

## 1. INTRODUCTION

Feed costs are a major part of total costs of milk production in dairy cattle (LEI/CBS, 1987). Therefore, it is important to optimize the level of nutrient intake (e.g. energy) and to optimize the sources of nutrient intake. The latter optimization aims to supply nutrients in their cheapest form (Korver, 1988). These optimizations require consideration of the different factors affecting feed intake capacity and nutrient requirements of dairy cows and the prices of different feed sources.
Factors affecting feed intake capacity of dairy cows can be divided into three main groups (Bines, 1979): feed, management and animal factors. Feed factors include composition and physical form of the diet. Important management factors are frequence and duration of access to feed. Animal

factors are: production levels (growth and milk production), size (volume abdominal cavity, live weight and degree of fatness), age or parity, physiological state (stage of lactation and pregnancy) and genetic merit for feed intake capacity (Bines, 1979; Meijs, 1981; Korver, 1982).
Genetic differences for feed intake capacity are observed both between (e.g. Korver, 1982; Oldenbroek, 1986; Taylor et al., 1986) and within dairy breeds (e.g. Gravert, 1985; Haapa and Syvävärvi, 1987). Published results on genetic differences for feed intake capacity indicate reasonable possibilities for genetic improvement. However, choosing which traits to include in the breeding goal and their relative weights (when applying selection index theory) also depend on the relative contribution of the trait to improvement of efficiency of production (economic value) (Harris, 1970).
In the literature, little attention has been given to the derivation of the economic value of feed intake capacity of dairy cows. The economic value of feed intake capacity can be derived according to two different principles:

1. Nutrient intake is determined by feed intake capacity (production levels are restricted by feed intake capacity): increase in feed intake capacity allows for an increase in production;
2. Nutrient intake is determined by nutrient requirement (fixed production levels): increase in feed intake capacity allows for a cheaper composition of nutrient intake.

Kanis (1988) calculated the economic value of intake capacity of pigs according to the first principle. Zeddies (1985) used the second principle to calculate the economic value of intake capacity of dairy cows. Values found by Zeddies (1985) ranged from 175-375 Dfl.(kg dry-matter.day$^{-1}$)$^{-1}$.cow$^{-1}$.year$^{-1}$, depending on the level of dry-matter intake. The choice of a principle in deriving the economic value of feed intake capacity will depend on the production circumstances, e.g. feeding strategy (restricted, according to (predicted) production or ad libitum) and quality and sources of feed as concentrate and roughage.

The aim of this study is:

1. to derive the economic value of feed intake capacity of dairy cows;
2. to quantify influences of animal and feed factors affecting feed intake capacity, and feed prices on the economic value of feed intake capacity.

## 2. METHOD

### 2.1. General aspects

In this study, the economic value of feed intake capacity is derived according to the second principle mentioned in the introduction: nutrient intake is determined by nutrient requirement. This approach implies that an increase in feed intake capacity allows for a cheaper composition of nutrient intake. Feeding according to requirement in an ad libitum feeding system is common in dairy cattle production in temperate zones and a main managemental problem is the choice of the relative supply of different feed sources to the dairy cow (e.g. concentrate/roughage ratio). This principle assumes a situation of energy balance for the cow, at least in the term of one lactation period. Following this principle, a change in composition of nutrient intake due to improvement of genetic merit, implies that an average kg of the total diet before improvement of genetic merit differs from an average kg of the total diet afterwards. Therefore, feed intake capacity should be defined in terms of dry-matter intake capacity of a reference feed.

The economic value of feed intake capacity is defined as 'the change in profit of the farm expressed per (average present lactating) cow, as a consequence of one unit change in genetic merit'. From the individual farmer point of view, profit (output - inputs) maximization is the adequate interest for calculation of economic values (Groen, 1989). Economic values are calculated on three bases (Groen, 1989): fixed number of animals at the farm, fixed input of a production-factor into the farm or fixed output of a product out of the farm. No limitations on input of energy resources on farm level exist in temperate zones. Assuming no changes in product output per animal, economic values of feed intake capacity will equal on base of fixed number of animals and fixed output (Groen, 1989). Within this study, economic values are calculated on base of a fixed number of average present lactating cows at the farm.

The model described by Groen (1988) is used to calculate the economic value of feed intake capacity. The model describes quantitative relationships

between levels of genetic merit and levels of inputs and outputs of the farm, in relation to production circumstances. Inputs of the farm are calculated from feed costs, labour costs, other variable costs and fixed costs; outputs from revenues of selling of milk and beef (animals).
Nutrient requirement of the animals is defined in terms of energy requirement. The model distinguishes between two feed components: roughage and concentrate. Intake ratio of roughage and concentrate of a dairy cow depends on the ratio between energy requirement and dry-matter intake capacity of a reference feed and on the quality of both feed components. Modelling of feed intake of dairy cows is described in more detail in paragraph 2.2. Dry-matter intake capacity in combination with feed quality is assumed to be sufficient to allow for the intake of required energy. Increase in genetic merit of feed intake capacity does not increase revenues (milk and beef production) nor does it affect the level of energy requirements (or intake) or input costs of labour or other variable and fixed costs. The economic value of feed intake capacity originates only from changes in feed costs due to an exchange in energy intake from concentrate to roughage (equation (1)). When energy from concentrate is more expensive than from roughage ($p_c > p_r$), a decrease in concentrate input will result in a positive economic value of feed intake capacity. The economic value of feed intake capacity, expressed as (Dfl.(kg dry-matter.day$^{-1}$)$^{-1}$.cow$^{-1}$.year$^{-1}$, is given by equation (1).

---

$$
\begin{aligned}
&\text{economic value feed intake capacity}\\
&\quad = 1/N * [\text{feed costs}_2 - \text{feed costs}_1]\\
&\quad = 1/N * [N * (-p_r RC_2 - p_c CC_2) - N * (-p_r RC_1 - p_c CC_1)]\\
&\quad = -p_r \delta RC - p_c \delta CC = (p_r - p_c)\delta CC \qquad (1)
\end{aligned}
$$

in which:

N : number of average present lactating cows,
RC : roughage intake (MJ $NE_l$.cow$^{-1}$.year$^{-1}$),
$p_r$ : price of roughage (Dfl.MJ $NE_l^{-1}$),
CC : concentrate intake (MJ $NE_l$.cow$^{-1}$.year$^{-1}$),
$p_c$ : price of concentrate (Dfl.MJ $NE_l^{-1}$),
Subscripts 1 and 2 refer to situations before and after change in genetic merit of feed intake capacity, respectively,

$\delta$ symbolizes the marginal change between the situations before and after change in genetic value of feed intake capacity.

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## 2.2. Modelling of feed intake of dairy cows

The principles of modelling feed intake of dairy cows within the model described by Groen (1988) are given in this paragraph.

Feed intake contains intake of roughage and concentrate. It is assumed that, per unit of energy, concentrate is more expensive than roughage. In order to minimize feed costs, roughage intake is maximized considering energy requirement, dry-matter intake capacity and feed quality. Feed intake is calculated per monthly period: ten months in lactation and two months dry-period. Twelve subsequent parities are distinguished. In the model, concentrate can be added to the diet in units of .1 kg dry-matter.day$^{-1}$. Minimum intake of concentrate is set equal to .2 and .1 kg dry-matter .day$^{-1}$ during lactation and dry-period, respectively.

Energy requirement is a function of maintenance, milk production, growth, pregnancy and mobilization/restoration of body-fat. Modelling of dry-matter intake capacity is given in equation (2). Dry-matter intake capacity is defined in terms of kilogram dry-matter intake of a reference feed. The reference feed used is: pasture grass cut at the grazing stage of first growth (25% crude fiber, 15% crude protein and .95 UFL net energy value per kg dry-matter; Jarrige et al., 1986). The extent to which intake of a kilogram dry-matter of concentrate and roughage takes up dry-matter intake capacity of the reference feed (fill values) is defined according to the principles of the INRA fill unit system (Jarrige et al., 1986). The fill value of roughage is set to 1.1. The total fill value of concentrate intake, F, is given by the non-linear function of concentrate intake C (kg dry-matter.day$^{-1}$): F = .26*C + .023*C$^2$). Energy content of roughage and concentrate are set to 6.21 and 7.21 MJ NE$_1$.kg dry-matter$^{-1}$, respectively (CVB, 1986).

---

$$DMIC_{ij} = \{(.135 * LWAGE_{.j}^{.75} + .20 * (FPCM_{.j} - 5000/305)) * DMIM_i + .20 * (FPCM_{ij} - FPCM_{.j})\} * .9 + (DMIC_b - 16.30) * DMIM_i/DMIM_2 \quad (2)$$

in which:

$DMIC_{ij}$ : dry-matter intake capacity in month i and lactation j in kg dry-matter of reference feed.$day^{-1}$,

$LWAGE_{.j}$ : mean age-dependent live weight during lactation j,

$FPCM_{.j}$ : mean FPCM production level during lactation j ($kg.day^{-1}$),

$FPCM_{ij}$ : mean FPCM production level during month i and lactation j ($kg.day^{-1}$),

$DMIM_i$ : multiplicative adjustment factor for month i in lactation,

$DMIC_b$ : basic level of dry-matter intake capacity of reference feed for a cow in second month of the third lactation, weighing 600 kg and yielding 6000 kg milk (4.2% fat and 3.4% protein) in a 305-day lactation period (kg dry-matter.$day^{-1}$).

---

According to ARC (1980), mean capacity for the entire lactation for cows yielding 5000 kg fat-protein-corrected-milk (FPCM; Korver, 1982) in a 305-day lactation equals .135 kg dry-matter per kg metabolic weight. Adjustment for higher yields is .2 kg dry-matter per day per kg FPCM per day (ARC, 1980). ARC (1980) gives adjustment factors for the effect of month in lactation on the dry-matter intake capacity. Preliminarily analysis showed insuffìcent adjustment by these factors. Therefore, based on Brown et al. (1977), an additional correction for the deviation of average daily milk yield per lactation month from average lactation yield is included. Dry-matter intake capacity simulated in this manner is converted to dry-matter intake capacity of the reference feed. The conversion factor is calculated from the levels of intake capacity of the standard cows of ARC (1980) and Jarrige et al. (1986) and is equal to .9 .

The level of genetic merit of feed intake capacity of dairy cows is expressed by the dry-matter intake capacity of reference feed for a cow in second month of third lactation, weighing 600 kg and yielding 6000 kg milk (4.2% fat and 3.4% protein) in a 305-day lactation period ($DMIC_b$). The basic level of genetic merit equals 16.30 kg dry-matter.$day^{-1}$. The economic value of feed intake capacity is calculated by raising $DMIC_b$ by one unit (from 16.30 to 17.30). This results in an increase in $DMIC_{ij}$ without changing levels of live weight and milk production. Within the model, it is implicitely assumed, that genetic correlations among dry-matter intake capacities for all months in all lactations are 1.

*Table 1: Values of variables of the model in the basic situation.*

| variable | value |
|---|---|
| energy content of roughage (MJ $NE_1$.kg dry matter$^{-1}$) | 6.21 |
| fill value roughage | 1.10 |
| energy content of concentrate (MJ $NE_1$.kg dry matter$^{-1}$) | 7.21 |
| milk carrier production[i] (kg) | 4655. |
| milk fat production[i] (kg) | 219. |
| milk protein production[i] (kg) | 171. |
| mature weight[ii] (kg) | 600. |
| price of roughage (Dfl.MJ $NE_1$$^{-1}$) | .06518 |
| price of concentrate (Dfl.MJ $NE_1$$^{-1}$) | .07242 |

*i : production of a first-parity cow in a 305-day lactation*

*ii: mature live weight of a cow*

## 2.3. Alternative feed, animal and price factors

Alternative feed factors considered are: energy content of roughage and fill value of roughage. Levels of milk production and mature weight are alternative animal factors. When varying milk production, fat and protein percentages are held constand at 4.34% and 3.38%, respectively. The effect of changing prices of concentrate and roughage energy is examined by lowering the price of roughage energy. Table 1 shows the levels of these variables within the basic situation.

## 2.4. Sensitivity of the model

In order to quantify the sensitivity of the model, economic values of feed intake capacity are calculated for situations with changed parameters of simulated dry-matter intake capacity (equation (2)): parameter kg dry-matter intake per kg metabolic weight (basic level .135) and parameter kg dry-matter per kg FPCM (basic level .20)).

*Table 2: Dry-matter intake capacity (DMIC), energy intake of concentrate (EIC) and roughage (EIR) and total dry-matter intake (TDMI), of a third parity cow in relation to genetic level of dry-matter intake capacity ($DMIC_b$).*

| month in | basic | | | | $DMIC_b$ + 1[i] | | |
|---|---|---|---|---|---|---|---|
| lactation | DMIC[ii] | EIC[iii] | EIR[iii] | TDMI[ii] | DMIC[ii] | EIC[iii] | TDMI[ii] |
| 1 | 13.9 | 48.3 | 62.7 | 16.8 | + .83 | - 7.94 | + .18 |
| 2 | 16.6 | 44.0 | 79.6 | 18.9 | + 1.00 | - 9.38 | + .21 |
| 3 | 17.6 | 33.9 | 89.6 | 19.1 | + 1.09 | - 9.38 | + .21 |
| 4 | 17.4 | 31.7 | 89.2 | 18.8 | + 1.10 | - 9.38 | + .21 |
| 5 | 17.3 | 26.0 | 90.5 | 18.2 | + 1.11 | - 8.66 | + .19 |
| 6 | 16.8 | 22.4 | 88.8 | 17.4 | + 1.10 | - 7.94 | + .18 |
| 7 | 15.4 | 26.7 | 79.2 | 16.5 | + 1.03 | - 8.66 | + .20 |
| 8 | 14.6 | 23.8 | 76.2 | 15.6 | + 1.01 | - 7.94 | + .17 |
| 9 | 13.7 | 19.5 | 72.0 | 14.3 | + .99 | - 5.05 | + .11 |
| 10 | 12.4 | 17.3 | 65.7 | 13.0 | + .95 | - 2.89 | + .06 |
| --[iv] | 10.0 | 7.2 | 47.3 | 8.6 | + .92 | 0.00 | .00 |
| -- | 10.0 | 9.4 | 54.3 | 10.0 | + .92 | - 2.16 | + .05 |

*i : results when dry-matter intake capacity genetically increased by 1 kg dry-matter.day$^{-1}$, expressed as a deviation from the basic situation*

*ii : kg dry-matter.day$^{-1}$*

*iii: MJ $NE_l$.day$^{-1}$*

*iv : dry-period*

## 3. RESULTS

### 3.1. Basic situation

In table 2, dry-matter intake capacity of reference feed, concentrate, roughage and total dry-matter intake of a third parity cow are given (see also figure 1), for both the basic situation and when feed intake capacity is genetically increased by 1 kg dry-matter.day$^{-1}$. In the basic situation, a third parity cow weighs about 585 kilograms and her production level equals 6754 kilogram FPCM during a 305-day lactation period. For each month, total dry-matter intake by roughage and concentrate exceeds intake capacity

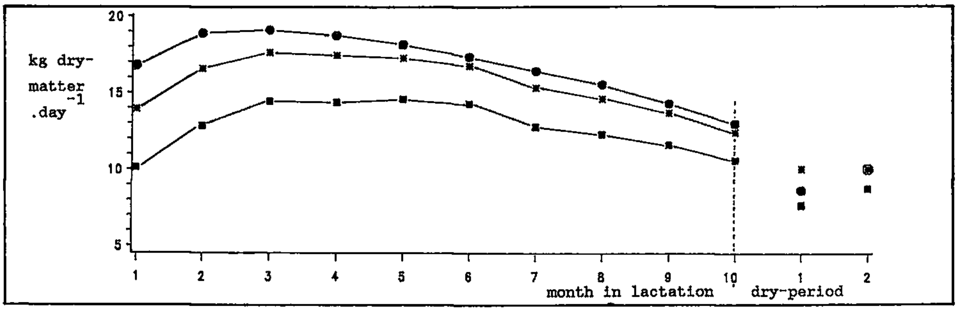


*Figure 1: Simulated dry-matter intake capacity (*), total dry-matter intake (●) and dry-matter intake for roughage (■) of a third parity cow.*

of reference feed. This is possible due to the low fill value of concentrate (paragraph 2.2.). Concentrate intake is highest in the first month in lactation, where the ratio between dry-matter intake capacity and energy requirement is lowest. Roughage intake is highest in the fifth month in lactation. Total dry-matter intake reaches its highest level in the third month in lactation.

The differences between months with respect to the increase in dry-matter intake capacity, due to an increase in $DMIC_b$ by one kg.day$^{-1}$, directly reflect the differences in adjustment factors between months in lactation ($DMIM_1/DMIM_2$, equation (2)). Summation of monthly changes gives a total decrease in concentrate intake by 2421 MJ $NE_1$.year$^{-1}$ and an increase in total dry-matter intake by 54.1 kg.year$^{-1}$ for a third parity cow. An increase in dry-matter intake capacity of reference feed of one kg.day$^{-1}$, results in an average increase of total dry-matter intake of roughage and concentrate of 54.1/365 = .15 kg.day$^{-1}$.

The energy intake of concentrate and roughage, and total dry-matter for each parity, in relation to level of $DMIC_b$, are given in table 3. Highest concentrate, roughage and total dry-matter intake are reached in fifth, twelfth and sixth lactation, respectively. Taking into account average herd composition and within-lactation culling of cows (Groen, 1988), the weighed average decrease in concentrate intake (due to increase in $DMIC_b$ by one kg.day$^{-1}$) equals 2561.3 MJ $NE_1$.year$^{-1}$. Multiplication of this amount by the price difference between concentrate energy and roughage energy (equation (1), table 1) gives an economic value of feed intake capacity of 18.55 Dfl.(kg dry-matter.day$^{-1}$)$^{-1}$.cow$^{-1}$.year$^{-1}$.

*Table 3: Energy intake of concentrate (EIC) and roughage (EIR) and total dry-matter intake (TDMI) for each parity in relation to genetic level of dry-matter intake capacity ($DMIC_b$).*

| parity | basic | | | $DMIC_b + 1^{i}$ | |
|---|---|---|---|---|---|
| | $EIC^{iii}$ | $EIR^{iii}$ | $TDMI^{ii}$ | $EIC^{iii}$ | $TDMI^{ii}$ |
| 1 | 8317.8 | 23595.2 | 4950.2 | - 2464.5 | + 55.0 |
| 2 | 8889.9 | 26314.8 | 5467.2 | - 2464.5 | + 55.0 |
| 3 | 9462.1 | 27297.7 | 5704.7 | - 2420.5 | + 54.1 |
| 4 | 9902.1 | 27615.9 | 5816.9 | - 2486.5 | + 60.5 |
| 5 | 10012.2 | 27695.5 | 5845.0 | - 2530.6 | + 56.5 |
| 6 | 9902.1 | 27828.4 | 5851.1 | - 2442.5 | + 54.5 |
| 7 | 9726.1 | 27804.2 | 5822.8 | - 2442.5 | + 54.6 |
| 8 | 9440.1 | 27854.3 | 5791.3 | - 2376.5 | + 53.1 |
| 9 | 9066.0 | 27887.6 | 5744.8 | - 2266.5 | + 50.6 |
| 10 | 8625.9 | 27909.0 | 5687.2 | - 2134.4 | + 47.7 |
| 11 | 8097.8 | 27958.0 | 5621.9 | - 1936.4 | + 43.2 |
| 12 | 7481.6 | 27983.3 | 5540.6 | - 1606.3 | + 35.9 |
| $w^{iv}$ | 9577.4 | 26785.4 | 5638.3 | - 2561.3 | + 57.2 |

*i : results when dry-matter intake capacity genetically increased by 1 kg dry-matter.day$^{-1}$, expressed as a deviation from the basic situation*

*ii : kg dry-matter.day$^{-1}$*

*iii: MJ $NE_1$.day$^{-1}$*

*iv : summation of lactations weighed by incidence within the herd*

### 3.2. Alternative factors and sensitivity of the model

Economic values of feed intake capacity for alternative situations are given in table 4.

A decrease in roughage quality (decrease in energy content or increase in fill value) will increase the proportion of concentrate energy in the diet. The change in intake from concentrate to roughage when increasing genetic merit of feed intake capacity, will be higher with a lower quality of roughage. Therefore, the economic value of feed intake capacity increases with decreasing energy content of roughage and increasing fill value of roughage.

*Table 4: Economic values of feed intake capacity for alternative situations ($Dfl.(kg\ dry\text{-}matter.day^{-1})^{-1}.cow^{-1}.year^{-1}$).*

| alternative | deviation[i] | level | economic value |
|---|---|---|---|
| basic | | | 18.55 |
| energy content roughage | - 11.1% | 5.52 | 19.48 |
| ($MJ\ NE_l.kg\ dry\text{-}matter^{-1}$) | + 11.1% | 6.90 | 6.09 |
| fill value roughage | - 9.1% | 1.00 | 5.32 |
| | + 9.1% | 1.20 | 19.63 |
| milk production | - 20% | 4036 | 4.71 |
| ($kg.lactation^{-1}$) | + 20% | 6054 | 23.15 |
| mature weight | - 20% | 480 | 22.64 |
| (kg) | + 20% | 720 | 8.71 |
| dry-matter intake capacity | - 1.0 | 15.30 | 22.62 |
| ($kg\ dry\text{-}matter.day^{-1}$) | + 1.0 | 17.30 | 8.66 |
| price roughage | - 11.1% | .05794 | 37.10 |
| ($Dfl.MJ\ NE_l^{-1}$) | | | |
| factor kg dry-matter | - .005 | .130 | 21.31 |
| per kg metabolic weight | + .005 | .140 | 13.58 |
| factor kg dry-matter | - .05 | .15 | 18.41 |
| per kg fpcm | + .05 | .25 | 18.64 |

*i: deviation from level in the basic situation*

The influences of feed quality are non-linear. Increase in milk production level or decrease in live weight or level of dry-matter intake capacity, will decrease the ratio between dry-matter intake capacity and energy intake requirement. Therefore, the economic value of feed intake capacity is increased. In conclusion, the economic value of feed intake capacity is

sensitive to both feed factors and animal factors.
A decrease in price of roughage energy from $65.18*10^{-3}$ to $57.94*10^{-3}$ (Dfl.MJ $NE_1^{-1}$) doubles the price difference between concentrate and roughage energy. Thus, the economic value of feed intake capacity is also doubled.
The influences of the parameters kg dry-matter per kg metabolic weight and kg dry-matter per kg FPCM are relatively small.

## 4. DISCUSSION AND CONCLUSIONS

From the results presented in table 3, it can be calculated that in the basic situation energy intake by concentrate equals 26.3% of total energy intake. The dry-matter intake by concentrate equals 23.5% of total dry-matter intake. After one unit genetic improvement, these percentages equal 19.3% and 17.1%, respectively. These figures denote that the economic value of feed intake capacity originates from an exchange in intake from concentrate to roughage (see also equation (1)). The economic value of feed intake capacity will be zero when prices of feed components are equal: an exchange in intake from concentrate to roughage will give no benefits.
The economic value of feed intake capacity is found to be highly sensitive to feed factors (energy content and fill value) and animal factors (milk production, mature weight, basic level of intake capacity). Moreover, the influences of these factors are non-linear. Non-linearity is a result of the non-linear fill value of concentrate: the levels of exchange in intake from concentrate to roughage (due to increase in genetic value of feed intake capacity) will differ according to the original level of concentrate intake.
A decrease in the qualities of feed components and an increase in energy requirements (higher production levels) will increase the economic value of feed intake capacity until the point where intake capacity on a lactation base and feed quality are no longer sufficient to cope with energy requirements. At such a situation, the economic value of intake is no longer quantified by the replacement of concentrate by roughage: the other principle as mentioned in the introduction "increase feed intake capacity allows for an increase in production" will have to be used.
Sensitivity towards the level of basic intake capacity corresponds to results of Zeddies (1985). However, the level of the economic value found

by Zeddies (1985) is much higher than the level found within this study (175-375 versus 5 - 25 Dfl.(kg dry-matter.day$^{-1}$)$^{-1}$.cow$^{-1}$.year$^{-1}$). This difference may be a result of differences in assumptions on feed factors, animal factors and feed prices. Differences may also be caused by a different level of definition of intake capacity. However, Zeddies (1985) doesnot describe enough details, to address the difference in economic value.

The trait 'feed intake capacity' as studied in this paper, is defined in terms of dry-matter intake capacity of a reference feed and the model allowed for a change in genetic value of this trait without changing levels of live weight and milk production. Increasing feed intake capacity as defined in this paper might be caused by a change in rumen capacity and/or an increased rumen outflow rate of feed particles (Orskov et al., 1988). The model used does not include a relationship between dry-matter intake capacity and changed energy requirements for growth and maintenance (Groen, 1988).

Feed intake capacity could be included in the breeding goal (or aggregate genotype). Possibilities of genetic improvement of feed intake capacity could be utilised within a Multiple-Ovulation-and-Embryo-Transplantation (MOET)-nucleus scheme (Nicholas and Smith, 1983) or by selection on base of performance testing of young AI-bulls (Korver et al., 1987). The question arises how to define the information index traits. In literature two approaches are discussed (Korver, 1988):

1. total dry-matter intake under circumstances with feeding according to milk yield;
2. total dry-matter intake under circumstances with feeding a fixed amount of concentrate and ad libitum roughage or with feeding a mixture of both components.

When using the first approach, the traits intake and milk yield will be totally confounded. The last approach could be used to estimate variation in dry-matter intake capicity between animals.

Research is needed to indicate the additional economic revenues of including of feed intake traits in the information index.

The sensitivity of the economic value of feed intake capacity requires a careful consideration of production circumstances in defining the breeding goal and asks for a further study on the necessity of a diversification of breeding goals including feed intake capacity.

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Chapter six

# Derivation of economic values in animal breeding. A theoretical comparison of different perspectives in production.

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**ABSTRACT**

This paper presents the concepts of economic production theory regarding different perspectives in deriving economic values in animal breeding. It is assumed that increase in genetic value allows a change in output along a given production function. Concepts denote that derivation of economic values according to different perspectives will result in different economic values when values of (saved) production-factors (from increase in genetic merit) differ between alternative uses. Imposition of three conditions will lead to equivalence of perspectives: (1) one-product situation or revenues of other products are negative costs, (2) equilibrium in a purely competitive industry, and (3) all costs are variable per unit product. Applicability of these conditions in agricultural industry is limited. The practical choice of a perspective has to reflect the individual producer's interest of selection (which is profit maximization) and base of evaluation (which is determined by production circumstances: fixed number of animals, fixed input or fixed output).

## 1. INTRODUCTION

Animal breeding is an important scientific and practical management field in European animal production. The general goal of animal breeding is: obtaining a new generation of animals that will produce more efficiently than the present generation, under future farm economic and social circumstances (Politiek, 1962). For practical application, this general goal is translated in a so called 'aggregate genotype' (Hazel, 1943). The aggregate genotype represents the genetic value of an animal, that is, the aggregated sum of the distinguished genotype traits, each trait being weighed by the value of that trait. The value of an aggregate genotype trait is determined by (Brascamp, 1978): (1) economic benefit of genetic superiority at the moment of expression (economic value), and (2) time and frequency of moments of future expression when genetic superiority is transmitted to offspring (cumulative discounted expression). This paper concerns derivation of economic values of aggregate genotype traits.

An important issue in deriving economic values of genotype traits is the choice of a perspective in production. Two aspects of perspective in production are distinguished: the interest of selection (that is the objective of production) and the base of evaluation. Harris (1970) distinguished three different interests: (1) to maximize profit (= revenues - costs), (2) to minimize costs per unit product, and (3) to maximize revenues/costs. In animal breeding, mainly the first and second interest are considered. The base of evaluation establishes size of the system considered in deriving economic values, according to social and economic production circumstances. Three possibilities are: (a) a fixed number of animals within the system, (b) a fixed amount of input of a production-factor into the system, and (c) a fixed amount of output of a product out of the system.

The choice of an interest of selection is related to whom is considered to be the principal decision-maker in animal breeding. Usually, individual farmers are affiliated to a co-operative or a private breeding organisation. Decisions on selection of animals are partly taken by the organisations and partly by the individual farmers. Harris (1970) stated, that breeding organisations should be concerned with the livestock producer's interest because the producer's primary reason to buy a certain breeding stock at a certain price is his assessment of how animals will contribute to the economic results of the firm. Improvement of genetic value is an area of technical development in animal production (Cochrane, 1958; Willer, 1967). Resembling Harris (1970), Cochrane (1958) stated that the final adoption of new techniques in agricultural production depends on the individual producer's assessment on reduction of costs and expansion of output resulting from implementation of these techniques. So, individual producer's interest of selection, and hence the interest of selection in deriving economic values should be the profit of the individual firms. However, in literature on defining breeding goals, it is often mentioned that breeding organisations are bound by a cost price interest in deciding on selection of animals (e.g. Brascamp et al., 1985). Little is known on the consequences of this difference in interest of selection.

The introduction of the quota system for milk production in the Europan Community in 1984, has resulted in the imposition of product output limitations at the farm level. The imposition of limitations influences

economic values of milk production traits in cattle breeding (Van Arendonk et al., 1985; Groen, 1989[b]). In literature only little attention has been paid to the theoretical back-ground in which different limitations affect derivation of economic values.
The need for a study on the theoretical economic consequences of the choice of both interest of selection and base of evaluation in deriving economic values, is stressed by the importance of economic values in determining the need for diversification of breeding goals in order to meet the range in production circumstances (Smith, 1985; Groen, 1989[a], 1989[b]).

The aim of this paper is to present the concepts of economic production theory in deriving economic values regarding different perspectives in production. From a comparison between the concepts within different perspectives, the practical choice of a perspective is discussed.

## 2. CONCEPTS OF ECONOMIC PRODUCTION THEORY

### 2.1. General aspects

Improvement of genetic merit is an area of technical development in animal production (Cochrane, 1958; Willer, 1967). In general, it is assumed that the implementation of new techniques sets up a new production function (Cochrane, 1958; Willer, 1967). On the other hand, economic values of improvements of genetic merit are commonly derived assuming no change in production function (e.g. Simm et al., 1987; De Vries, 1988; Groen, 1988). It is assumed that the level of genetic merit restricts the output level of a product; so, increase in genetic merit allows a change in output along a given production function. Figure 1 gives an example of this approach. This example, giving the relationship between fat-protein-corrected milk production per animal and the costs of energy requirement per animal, is drawn from the model of Groen (1988). Fixed costs only represent maintenance energy requirements of an animal. Actual maximum level of fpcm of Dutch Black and White cattle is about 55 $kg.day^{-1}$, which is still in the part of decreasing average total costs of energy requirement.

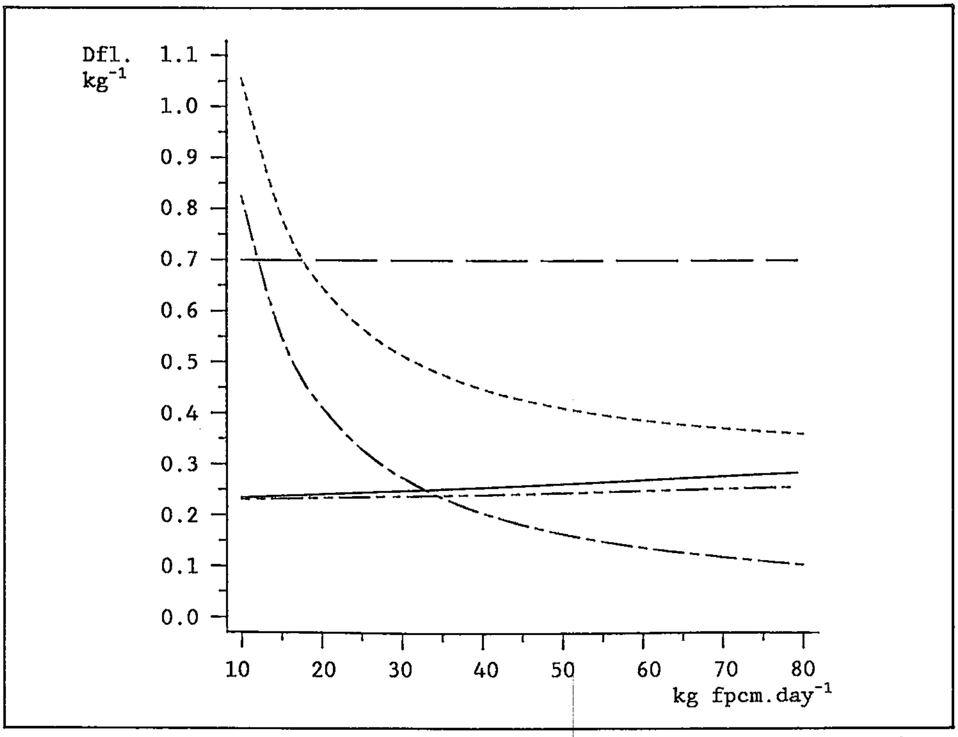


*Figure 1. The relationship between energy requirement per animal and fat-protein corrected milk production (fpcm) per animal: marginal revenues (— —), average total costs (- - -), marginal costs (——), average variable costs (—- -), average fixed costs (— - —).*

In this paper, six alternative perspectives in production in deriving economic values are considered: two interests of selection (1) profit and (2) cost price per unit product; three bases of evaluation (a) fixed number of animals, (b) fixed input of a production-factor and (c) fixed output of a product. For these six alternative perspectives, economic values expressed in concepts of economic production theory are derived, starting from a situation with one product and one variable production-factor per animal. The micro-economic approach of an individual farm is chosen. Equation (1) gives the revenues and costs of the farm.

$$\text{revenues farm} = Y\ p_y = n\ y\ p_y \qquad (1a)$$

$$\text{costs farm} = X_v\ p_v + C_{fa} + C_{ff} = n\ (x_v\ p_v + c_{fa}) + C_{ff} \qquad (1b)$$

in which:

- $n$ : number of animals at the farm,
- $y$ : level of product output per animal ($Y = n\ y$),
- $p_y$ : price per unit product,
- $x_v$ : level of input of production-factor v, variable per animal ($X_v = n\ x_v$),
- $p_v$ : price per unit production-factor v,
- $c_{fa}$ : costs of input of production-factor fa, fixed per animal ($C_{fa} = n\ c_{fa}$),
- $C_{ff}$ : costs of input of production-factor ff, fixed per farm;

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Equation (2) gives profit and costs per unit product of the farm.

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$$\text{profit farm} = Y\ p_y - (X_v\ p_v + C_{fa} + C_{ff}) \quad (2a)$$

$$\text{costs per unit product farm} = (X_v\ p_v + C_{fa} + C_{ff})/Y \quad (2b)$$

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The economic value of a genotype trait represents the change in profit or costs per unit product as a result of one unit change in genetic merit of the trait considered. It is assumed, that change in genetic merit of an animal will change $y$ and $x_v$ by $dy$ and $dx_v$ per animal, respectively. Depending on base of evaluation, changes in $y$ and $x_v$ give rise to changes in $n$, $Y$, $X_v$ and/or $C_{fa}$. On base of fixed number of animals, it is assumed that marginal product produced and marginal production-factor required per animal is sold and purchased at the market, respectively. On base of fixed input it is assumed, that the amount of production-factor v (variable per animal) used at the farm ($X_v$) is fixed. This implies, that an increase in requirement of v per animal ($dx_v$) will not increase the purchase of v at the market, but will reduce the number of animals at the farm. The relationship between level of $dx_v$ and reduction in number of animals is given by equation (3a). Analogously, on base of fixed output it is assumed, that the amount of product Y produced at the farm is fixed. This implies, that an increase in production per animal ($dy$) will not increase the selling of product at the market, but will reduce number of animals at the farm. The reduction in number of animals is given by equation (3b).

$$(n+dn)(x_v+dx_v) = n\ x_v \quad \text{--->} \quad dn = n * [-\ dx_v/(x_v+dx_v)] \qquad (3a)$$
$$(n+dn)(y+dy) = n\ y \quad \text{--->} \quad dn = n * [-\ dy/(y+dy)] \qquad (3b)$$

Related to the micro-economic approach, assuming agricultural price-taker markets, the prices of products and production-factors are constant. Change in profit of the farm is calculated as 'profit after change in genetic merit' minus 'profit before change in genetic merit', as the interest is maximization of profit. Change in cost price is calculated as 'cost price before change in genetic merit' minus 'cost price after change in genetic merit', as the interest is minimization of cost price. Economic values within the cost price interest will be positive when increase in genetic merit results in a decrease in cost price per unit product. The levels of genetic merit of aggregate genotype traits are tied up to individual animals. Therefore, in deriving economic values, changes in profit of the farm are divided by number of animals n (present before change in genetic merit). Changes in cost price per unit product for the farm are multiplied by the original level of output y per animal.

### 2.2. Derived concepts of economic values

#### 2.2.1. Profit interest

The economic value (EV) within the profit interest is given by equation (4).

$$\text{EV 'profit'} = 1/n * \{\ \text{d(revenues farm)} - \text{d(costs farm)}\ \} \qquad (4)$$

On base of **fixed number of animals**, changes in revenues and costs of the farm originate directly from changes in revenues and costs per animal multiplied by number of animals. So, d(revenues) = n dy $p_y$ and d(costs) = n $dx_v$ $p_v$. In other words, the economic value 'profit, fixed number' is equal to the margin between marginal revenues and marginal costs of production of dy units product per animal (equation (5)).

$$\text{EV 'profit, fixed number'} = dy\ py - dx_v\ p_v \qquad (5)$$

On base of **fixed input**, change in revenues of the farm originates from an increase in production per animal corrected for change in number of animals: d(revenues) = n dy $p_y$ + dn (y+dy)$p_y$ (dn is given by equation (3a)). Change in number of animals is multiplied by production level after genetic improvement; change in number of animals is necessarily after improvement of genetic merit. Within this perspective both $X_v$ and $C_{ff}$ are fixed, change in costs of the farm originate from reduction in $c_{fa}$ only: d(costs) = dn $c_{fa}$. Inserting these d(revenues) and d(costs) into equation (4), and rewriting the completed equation gives equation (6). Equation (6) shows, that costs of dy units of product per animal originate from 'deprivation of average revenues and reduction of costs fixed per animal' per unit of required variable input per animal.

EV **'profit, fixed input'** $= dy\ p_y - dx_v[(y+dy)p_y - c_{fa}]/[x_v+dx_v]$ (6)

On base of **fixed output**, change in revenues of the farm are zero. Change in profit of the farm originates only from a change in costs of production-factors v and fa: change in costs of v per animal ($dx_v\ p_v$) corrected for change in costs due to a change in number of animals (dn * $[(x_v+dx_v)p_v + c_{fa}]$; dn is given by equation (3b)). The value of dy units of product originates from a reduction in variable costs of the farm due to a decrease in number of animals.

EV **'profit, fixed output'** $= dy[(x_v+dx_v)p_v + c_{fa}]/[y+dy] - dx_v\ p_v$ (7)

### 2.2.2. Cost price interest

The economic value within the cost price interest is given by equation (8): the cost price before genetic improvement minus the cost price after genetic improvement, multiplied by original level of output y per animal.

EV **'cost price'** =

y { (costs farm)/Y - (costs farm + d(costs farm))/(Y + dY) } =

y/(Y+dY) { dY/Y * (costs farm) - d(costs farm) } (8)

On base of a **fixed number of animals**, d(costs farm) is given by n * marginal costs per animal = n $dx_v$ $p_v$. Change in production of the farm dY = n dy. Rewriting the completed equation (8) gives equation (9). The economic value 'cost price, fixed number' is positive, when marginal costs of producing dy are smaller than average total costs of dy units product.

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EV **'cost price, fixed number'** =

$$y/(n\ y + n\ dy)\ \{n\ dy/(n\ y)\ (n\ x_vp_v + C_{fa} + C_{ff}) - n\ dx_vp_v\} =$$

$$dy\ [n\ x_vp_v + C_{fa} + C_{ff}]/[n\ y + n\ dy] - [y/(y+dy)]dx_vp_v =$$

$$dy\ [n(x_v+dx_v)p_v + C_{fa} + C_{ff}]/[n\ y + n\ dy] - dx_vp_v \quad (9)$$

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On base of **fixed input**, d(costs farm) are dn $c_{fa}$; both $X_v$ and $C_{ff}$ are fixed (dn is given by equation (3a)). Change in production of the farm is: dY = n dy + dn(y+dy). The resulting economic value 'cost price, fixed input' is given by equation (10). dy is valued by the average total costs per unit product after improvement of genetic merit; $dx_v$ is valued by the average fixed costs per unit $x_v$.

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EV **'cost price, fixed input'** =

$$y/[(n+dn)(y+dy)] * \{\ [(n\ dy/(n\ y)]\ [costs\ farm] + [(dn(y+dy)/(n\ y)]\ [costs\ farm] - dn\ c_{fa}\} =$$

$$dy\ [costs\ farm]/[(n+dn)(y+dy)] + [dn/n(n+dn)]\ [costs\ farm] - [dn/(n+dn)]\ [y/(y+dy)]\ c_{fa} =$$

$$dy\ [n\ x_vp_v + C_{fa} + C_{ff}]/[(n+dn)(y+dy)] + [dn/n(n+dn)]\ [n\ x_vp_v + C_{fa} + C_{ff}] - [dn/(n+dn) + (n\ dy)/(n+dn)(y+dy) - dy/(y+dy)]\ c_{fa} =$$

$$dy\ [nx_vp_v + (n+dn)c_{fa} + C_{ff}]/[(n+dn)(y+dy) - dx_v\ [nx_vp_v + C_{ff}]/[(x_v+dx_v)(n+dn)] \quad (10)$$

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On base of **fixed output**, $dY = 0$ and d(costs farm) $= n\ dx_v\ p_v + dn\ ((x_v+dx_v)p_v + c_{fa})$, in which dn is given by equation (3b). Completing and rewriting of equation (8) gives equation (11). The economic value 'cost price, fixed output' equals the economic value 'profit fixed output' (equation (7)).

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EV **'cost price, fixed output'** =

$$y/(n\ y)\ \{0 - n\ dx_v p_v - n * [-\ dy/(y+dy)]\ [(x_v+dv)p_v + c_{fa}]\} =$$

$$dy\ [(x_v+dv)p_v + c_{fa}]/[y+dy] - dx_v p x_v \qquad (11)$$

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## 2.3. Comparison of concepts within different perspectives

Table 1 summarizes the concepts of production theory within each perspective, as given by equations (5), (6), (7), (9), (10) and (11). Concepts are derived for a situation with one product and one variable production-factor per animal. However, concepts can easily be extended to situations with more products and more variable production-factors. The costs of other production-factors with a variable input are always to be considered in average variable or average total costs. When the inputs of other variable production-factors are influenced by the level of genetic merit, the marginal costs of production will contain more terms. Analogously, the revenues of other products are always to be considered in average revenues. When the output level of other products is influenced by the level of genetic merit, marginal revenues will contain more terms. When the output level of other products is not influenced, within the profit interest average variable costs are extended. In the latter case, the revenues of other products are 'negative costs' components. For the cost price interest, consideration of the revenues of other products to be negative costs is optional. For example, in dairy cattle production the gross or net cost price of milk can be calculated. The net cost price considers all costs minus revenues of beef production per unit milk.

The essence of improvement of efficiency of a production system is: saving inputs of production-factors per unit product and/or a change towards use

*Table 1: Economic values expressed in concepts of economic production theory.*

| base | interest: profit | interest: cost price |
|---|---|---|
| fixed number of animals | marginal revenues$^{i}$ - marginal costs$^{ii}$ | average total costs$^{i}$ - marginal costs$^{ii}$ |
| fixed input ($X_v$) | marginal revenues$^{i}$ - average (revenues - fixed costs per animal)$^{iii}$ | average total costs$^{i}$ - average fixed$^{iv}$ costs farm$^{iii}$ |
| fixed output (Y) | average variable costs$^{i}$ - marginal costs$^{ii}$ | average variable costs$^{i}$ - marginal costs$^{ii}$ |

*i : per dy units of product*

*ii : per dy units of product, corresponding to $dx_v$ units production-factor*

*iii: per $dx_v$ units of production-factor*

*iv : on base of input fixed, fixed costs farm include $X_v$ and $C_{ff}$*

of cheaper production-factors. Saved production-factors can either be used in the system where they are saved from (and thus extend product output of this system) or can be transferred to another system (via the market) (Willer, 1967). Likewise, additionally required production-factors are either to be drawn from the market or from an alternative use in the system. Obtained differences in concepts of production theory originate directly from differences in assumed use of saved production-factors. For the 'profit, fixed number' perspective, saved production-factors are purchased at the market. In other words, differences in concepts between perspectives will indeed lead to differences in economic values when the values of (saved) production-factors differ between alternative uses.

In deriving economic values, the values of production-factors are commonly exogeneous parameters. The degree to which economic values derived according to different perspectives in production differ, depends on the origin of the value parameters and, therein, on the assumed market situation. Given some conditions on the origin of the value parameters, economic values may equal when derived according to different perspectives.

Assuming (1) markets of products and production-factors to be purely competitive markets and (2) industry and all individual firms to be in equilibrium, market prices will equal average total costs of production (Stonier and Hague (1964). So, economic values on base of fixed number of animals are equivalent when derived within profit and cost price interests (see also Brascamp et al. (1985)). Given these conditions, also economic values on base of fixed input are equivalent; revenues equal fixed costs per animal ($C_{fa}$) + 'fixed' costs $X_v p_v$ + other fixed costs of the farm $C_{ff}$.

On base of fixed output, economic values within a profit interest are equivalent to economic values within a cost price interest. These economic values will also be equivalent to economic value 'fixed number, cost price' when (3) all costs of the farm are considered to be variable per unit product. This equivalence was pointed out by Smith et al. (1986), who proposed to express fixed costs per animal or per farm, like variable costs, per unit of output.

Assuming that all costs are variable and that also the costs of producing the variable production-factor at the farm equals the market price, all perspectives are equivalent.

Denoted equivalences of perspectives in deriving economic values will also be valid in multiple product or variable production-factor situations when, in the cost price interest, revenues of other products are considered to be negative cost components of the farm.

The optimum level of genetic merit of a trait is denoted by the level at which the economic values is zero. This means, that related to the degree in which economic values differ when derived according to different perspectives, also the optimum levels of genetic merit differ.

## 3. DISCUSSION AND CONCLUSIONS

Chapter two presents the concepts of economic production theory regarding different perspectives in deriving economic values. The concepts denote that derivation of economic values according to different perspectives will result in different economic values when the values of production-factors differ between alternative possibilities of use. When three conditions are imposed, economic values will be equivalent when derived according to different perspectives. This means, that the extent to which economic values differ when derived for different decision-makers (individual farmer versus breeding organisation) or when derived for different economic and social circumstances, is related to the extent to which the second and third equivalence conditions hold in the agricultural industry in which economic values are derived.

Applicability of the second condition, equilibrium in a purely competitive industry, does not stand to reason. The main characteristics of a purely competitive industry are: homogeneous products and production-factors, large number of producers and consumers involved, and absence of barriers to enter or leave the market (Stonier and Hague, 1964).
Market equilibrium will never actually exist. However, it is irrelevant to allow seasonal, cyclical or non-systematic price-oscillations (Dahl and Hammond, 1977), causing temporarily high or low profits in an industry, to influence breeding goals. Equilibrium prices are to be estimated from recorded data.
In agricultural industries, products and production-factors are commonly heterogeneous. Heterogenity of products and production-factors leads to division of markets (Dahl and Hammond, 1977). If the number of market participants remains large, heterogenity of products and production-factors will not violate assumptions on purely competition. Heterogenity of products and production-factors is also related to differences in organisation and appearance of firms within an industry. These differences do not undermine existence of long-term equilibrium prices (Stonier and Hague, 1964), but they cause the average costs of production to be different for individual firms. Given equilibrium prices, some firms will be able to earn 'supernormal' profits; other firms will be just efficient enough to continue production (Stonier and Hague, 1964). As an important result, the equivalence of perspectives will not be valid from an individual producer's point of view.
In general, the number of market participants in agricultural industries is large (Andriessen et al., 1980). An individual producer or consumer trades only such a small portion of the total supply on the market, that he has no

independent influence on prices. However, governments may take up a position as a market participant in order to decrease market instability. Governmental market or income policies directly or indirectly support market prices of agricultural products. Long-term discrepancy between supported prices and average total costs of production may lead to an unbalance between demand and supply of products. Therefore, governmental policies often enclose laws to limit product output (e.g. quota systems for milk production). Governmental output limitations and also indivisibility of production-factors restrict a free exchange of production-factors between alternative production uses.

The third condition required for equivalence of perspectives is: all costs are variable costs per unit product. Smith et al. (1986) argued to apply this condition in deriving economic values together with the condition of a fixed output (rescaling). According to Smith et al. (1986) application of these conditions restricts the derivation of economic values to calculation of changes in cost price per unit product. This equivalence of perspectives 'profit, fixed output' and 'cost price, fixed number' also appears from the concepts of economic production theory (table 1). Smith et al. (1986) argued that it should be assumed that resources are efficiently used, and that changes in output require proportional changes in input. Hence, fixed costs might be assumed to be variable costs per unit product. Animal breeding is a part of strategic (long-term) planning of production. Therefore, it is appropriate to consider all costs to be variable in time, in deriving economic values. However, it is important to face that costs may be fixed (constant or discontinuously variable) with respect to size of the enterprise (Horring, 1948). Considering these fixed costs to be variable per unit product requires an assumption on (optimum) size of the enterprise. If one assumes that all enterprises have the same largeness and that changes in number of animals in the industry is accomplished by change in number of enterprises, the condition on fixed costs is arithematically correct. However, structural developments in industry are detached from improvements in efficiency of production.
Smith et al. (1986) argued that the conditions mentioned above should be applied, as only savings in costs per unit product should be included. Indeed, saving inputs per unit product is the essence of increasing

efficiency. But, as argued in paragraph 2.3., perspectives in production differ in the way of valuation of saved production factors. Smith et al. (1986) stated correctly that some of the change in profit from change in product output might also be matched simply be rescaling the size of the enterprise. However, this does not mean that it should be denied that implementation of new techniques leads to among others expansion of product output (when saved production-factors are used in the same enterprise, Willer, 1967), and, in the long run, might influence the structure of industry.

Based on the considerations given, it is concluded that the applicability of equivalence of perspectives in deriving economic values is limited. Still, the practical choice of an interest of selection has to reflect the individual producer's long-term interest of selection and base of evaluation (see e.g. Cochrane, 1958; Harris, 1970). This long-term interest is profit maximization of the individual firm. In the long run, new techniques will be adopted by most producers and as a result, prices of products will decrease (Cochrane, 1958). When economic values are derived using a model at sector or national level, inclusion of the price effects on long-term profit of the firms is possible.
In principal, there are two categories of innovation of new techniques: 'autonomous' and 'induced', not subject to and subject to economic factors, respectively (Willer, 1967). Animal breeding is an innovation of the second category: the values of production-factors saved due to genetic improvement are major factors inducing the way to improve genetic value. This implies, among others, that market participants who determine market prices (e.g. organized agricultural industry or governments) possess important tools to direct genetic improvement. Governments can create social and economic circumstances (like market, income and environmental health policies) to impose their objectives to individual producers. In general, the production circumstances, imposed by governments or individual producer's situations will determine the practical choice of a base of evaluation (fixed number of animals, fixed input or fixed output). The imposition of limitations influences economic values of e.g. dairy cattle production traits (Van Arendonk et al., 1985; Groen, 1989[b]). Concepts of economic production theory in different perspectives, presented in this paper, denote the theoretical

back-ground of the observed influences of the imposition of limitations. Concepts presented also denote the consequences of use of different interests of selection by different decision-makers in animal breeding and that the theoretical base for a diversification of breeding goals among (groups of) farms is created by governmental policies, heterogenity of products and heterogenity and indivisibility of production-factors.

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Chapter seven

# Influences of production circumstances on the economic revenues of cattle breeding programmes.

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**ABSTRACT**

The economic values of cattle production traits are sensitive to production circumstances. This sensitivity of economic values implies that: (1) production circumstances influence level of revenues of breeding programmes, and (2) losses in revenues of breeding programmes occur when circumstances used in defining the breeding goal are incorrect with regard to actual production circumstances at the moments of expression of genetic superiorities. In this study, these effects are quantified for two sets of aggregate genotype and information index traits, including milk production traits, feed intake capacity and live weight, and 24 situations of production circumstances (including output limitations, milk production level, energy content roughage and product and production-factor prices). Results indicate that type of output limitation is the most important factor in determining levels of revenues. Also, incorrect prediction of type of limitation leads to highest losses in revenues found (1 to 6% of maximum revenues). Obtained levels of losses in revenues due to incorrect prediction of production circumstances seem too low to justify complete diversification of cattle breeding goals within a breeding organisation, except for different situations of output limitations.

## 1. INTRODUCTION

The general goal in animal breeding is: obtaining a new generation of animals that will produce more efficiently under future farm economic and social circumstances than the present generation of animals (Politiek, 1962). For practical application, this general goal is translated in an aggregate genotype (Hazel, 1943). The breeding goal provides a basis for a breeding programme. Revenues of breeding programmes are the future economic benefits of improved genetic merit of animals. The level of economic revenues of breeding programmes is determined by (Brascamp, 1978) (1) time and frequency of future expression of genetic superiority and (2) economic benefit of genetic superiority at the moment of expression (economic value). In order to optimize the levels of genetic improvement of aggregate genotype traits, these traits are weighed by their predicted contribution to economic revenues (Hazel, 1943).

Economic values of cattle production traits are sensitive to production circumstances (Adelhelm et al., 1972; Van Arendonk et al., 1985; Zeddies, 1985; Groen, 1989[a], 1989[b]; Groen and Korver, 1989). This sensitivity of economic values has two aspects. First, the level of economic revenues of breeding programmes is influenced by production circumstances. Investments in breeding programmes anticipate revenues. Therefore, expected levels of revenues are important in deciding on (optimum) levels of investment. Secondly, incorrect prediction of production circumstances may lead to sub-optimum weighing of traits within the aggregate genotype and, therefore, to losses in economic revenues of breeding programmes. Incorrect prediction of production circumstances can be a result of uncertainty about future production circumstances or heterogenity of production circumstances among farms obtaining their breeding stock from a breeding programme. So, in the second case, predicted production circumstances may be correct as far as 'average' circumstances are considered, but may be incorrect regarded from an individual producers point of view. As discussed by Smith (1985, 1986), uncertainty and heterogenity of production circumstances may lead to a diversification of breeding goals. More research is required to study the carrying-over-effects of sensitivity of economic values to production circumstances on economic revenues of cattle breeding goals.

The aim of this study is:

1. to determine to what extent the level of economic revenues of cattle breeding programmes depends on production circumstances;
2. to quantify losses in economic revenues of cattle breeding programmes due to incorrect assumptions on production circumstances in defining cattle breeding goals.

## 2. METHOD

### 2.1. General aspects

The choice of an aggregate genotype is the starting point in setting up breeding programmes. The aggregate genotype is used to represent the genetic merit of an animal: the sum of its genotypes for several traits (assuming a distinct genotype for each economic trait), each genotype being weighed by the relative economic value of that trait (Hazel, 1943). Selection for improved genetic merit is practiced by selecting for a correlated information index. The index is based on phenotypic performance of the animal itself and/or of related animals. In this study, the following notation is used:

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$$H_{jkl} = \mathbf{a}'_{kl}\mathbf{g}_j \tag{1a}$$

$$I_{jkl} = \mathbf{b}'_{jkl}\mathbf{x}_j \tag{1b}$$

in which:

- $H_{jkl}$ : aggregate genotype of an animal within set j, situation k and selection path l ($Dfl.cow^{-1}$),
- $\mathbf{a}_{kl}$ : (m*1) vector with discounted economic values of m aggregate genotype traits in situation k and selection path l ($Dfl.cow^{-1}.unit^{-1}$),
- $\mathbf{g}_j$ : (m*1) vector with genetic superiorities of m aggregate genotype traits (unit; e.g. kilogram),
- $I_{jkl}$ : information index value of an animal in set j, situation k and selection path l ($Dfl.cow^{-1}$),
- $\mathbf{b}_{jkl}$ : (n*1) vector with regression coefficients of n information index traits in set j, situation k and selection path l ($Dfl.cow^{-1}.unit^{-1}$),
- $\mathbf{x}_j$ : (n*1) vector with phenotypic performance for n information index traits (unit).

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Two alternative sets of aggregate genotype and information index traits are studied and, within each set, 24 alternative situations of production circumstances. Discounted economic values of genotype traits are calculated per situation as a function of cumulative discounted expression and economic value (equation (2a)). The economic value of a trait expresses to what extent economic efficiency of production is improved by an increase of one unit genetic merit of that trait. The cumulative discounted expression of a trait reflects time and frequency of future expression of a superior genotype originating from a selected individual (Brascamp, 1978). Cumulative discounted expressions differ between selection paths: the selected individual is a sire to breed sires, a sire to breed dams, a dam to breed sires or a dam to breed dams (path SS, SD, DS and DD, respectively). Calculation of regression coefficients $b_{jkln}$ (equation (2b)) maximizes the correlation between aggregate genotype and information index (Hazel, 1943).

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$$a_{kl} = c'_{l} v_{k} \tag{2a}$$

$$b_{jkl} = P_{j}^{-1} G_{j} a_{kl} \tag{2b}$$

in which further:

- $c_l$ : (m*1) vector with cumulative discounted expression of m aggregate genotype traits in path l ($cow^{-1}.years.cow^{-1}$),
- $v_k$ : (m*1) vector with economic values of m aggregate genotype traits in situation k ($Dfl.cow^{-1}.year^{-1}.unit^{-1}$),
- $P_j$ : (n*n) matrix with covariances between n information index traits,
- $G_j$ : (m*n) matrix with covariances between m aggregate genotype traits and n information index traits.

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After one round of selection, genetic superiority (GS) of selected animals for each genotype trait m equals (Cunningham, 1969):

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$$GS_{jklm} = (i_l/\sigma_{Ijkl}) * b'_{jkl}(\text{column m of } G_j) \tag{3}$$

in which further:

- $\sigma_{Ijkl}$ = standard deviation of index in set j, situation k and path l ($= \surd(b'_{jkl} G_j a_{jkl})$; Cunningham, 1969),
- $i_l$ = selection intensity in path l.

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In this study it is assumed that production circumstances only influence breeding programmes by their influences on economic values ($v_k$). A breeding programme is defined on base of predicted situation k and corresponding discounted economic values $a_{klm}$. Obtained economic revenues (OER; equation (4)) is the sum of genetic superiorities for all aggregate genotype traits (m) due to selection in all paths (l), valued by 'actual' discounted economic values ($a_{k_a lm}$). The actual situation ($k_a$) is the real occuring situation at the moment and place of expression of genetic superiority.

$$OER_{jk} = \sum_l \sum_m a_{k_a lm} * GS_{jklm} \qquad (Dfl.cow^{-1})$$

$$= \sum_l \sum_m [a_{k_a lm} * (i_l/\sigma_{Ijkl}) * b'_{jkl}(\text{column m of } G_j)]$$

$$= \sum_l [(i_l/\sigma_{Ijkl}) * b'_{jkl} G_j a_{k_a l}] \qquad (4)$$

When $a_{kl} = a_{k_a l}$, in other words, predicted production circumstances equal actual circumstances, optimum levels of improvement per trait and maximum economic revenues (MER) of the breeding programme will be obtained (Cunningham, 1969):

$$MER_{jk_a} = \sum_l [i_l * \sigma_{Ijk_a l}] \qquad (Dfl.cow^{-1}) \qquad (5)$$

For the first aim of this paper, calculating of the levels of economic revenues for alternative production circumstances, it is assumed that predicted production circumstances equal actual production circumstances (influences of different economic values on MER are calculated). Influences are studied for a given set of aggregate genotype and information index traits and assuming equal cumulative discounted expressions and selection intensities. Selection intensities used are 2.135, 1.842, 3.367 and .424 for paths SS, SD, DS and DD, respectively. Selection intensities are derived from a breeding programme based upon the situation of Dutch dairy cattle population in 1986/1987 (appendix 1).

For the second aim of this paper, calculating losses in economic revenues of cattle breeding programmes, it is assumed that, due to heterogenity and/or uncertainty, predicted economic values differ from actual economic values. Obtained genetic superiorities originate from incorrectly predicted production circumstances, but are to be valued by actual discounted economic values (equation (4)). Losses are quantified using equation (6). Figure 1 shows schematically the calculation of OER, MER and OMMER.

Obtained Minus Maximum Economic Revenues = $\qquad (Dfl.cow^{-1})$

$$\text{OMMER (situation k)} = OER_{jk} - MER_{jk_a} \qquad (6)$$

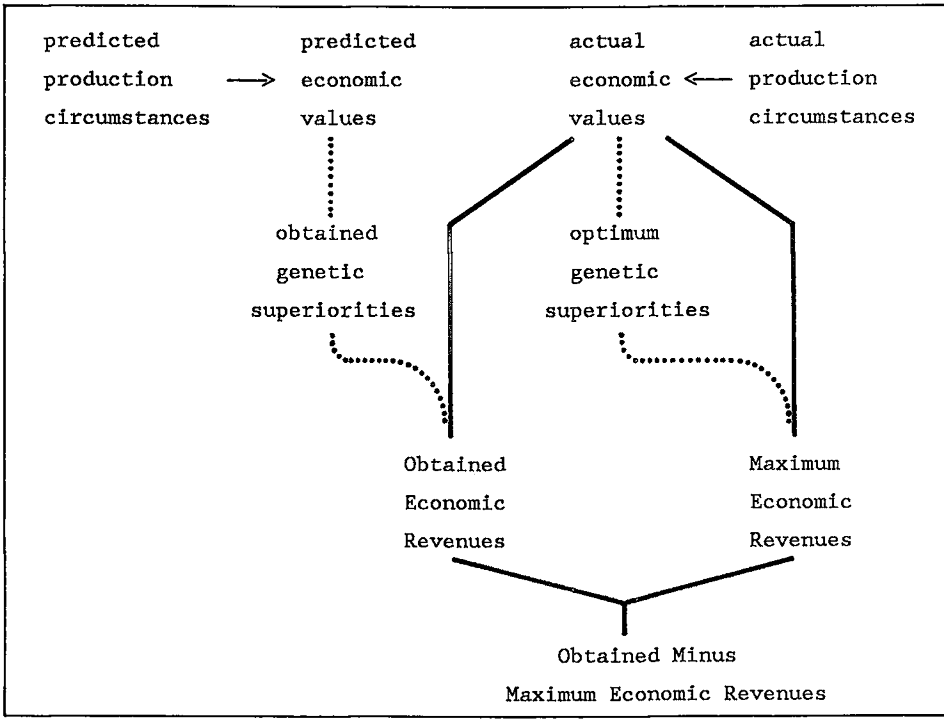


*Figure 1. Derivation of economic revenues of breeding programmes.*

**2.2. Aggregate genotype and information index traits**

Aggregate genotype traits considered are:

Set 1: (m=3) carrier, fat and protein production (kg first lactation);

Set 2: (m=5) carrier, fat and protein production (kg first lactation), live weight and feed intake capacity.

Live weight is considered to be asymptotic mature live weight, adjusted for influences of stage of lactation and pregnancy (Von Bertalanffy-curve; Groen, 1988). Feed intake capacity is defined in terms of kilograms dry-matter of a standard reference feed (Groen, 1988).

Two sets are studied in order to quantify to what extent influences of production circumstances on MER and OMMER depend on aggregate genotype traits, and not to compare levels of MER and OMMER between the sets. Set 1 is based on the present Dutch situation for estimating breeding values for milk production (Wilmink and De Graaf, 1986; NRS, 1987). Feed intake capacity and live weight are included in set 2 because of importance of the traits and available knowledge on economic values and genetic and phenotypic parameters. Beef production traits related to new-born calves are not included in set 2. It can be expected that in the (near) future, as a consequence of application of reproduction techniques (embryo transfer, sperm and embryo sexing) in combination with beef crossing, selection for these traits will be in specialized beef breeds only (Groen et al., 1988). Aggregate genotype traits (per set) are equal for all selection paths; information index traits differ whether selection is for sires or for dams.

Set 1: paths SS and SD: (n=3) estimated breeding values (based on production of 70 (effective) daughters) for milk, fat and protein production.
paths DS and DD: (n=9) milk, fat and protein production (kg first lactation) of cow, and estimated breeding values for milk, fat and protein of her sire and maternal grandsire.

Set 2: paths SS and SD: (n=5) information index traits set 1 + estimated breeding values (based on figures of 20 daughters) for weight at first calving and feed intake capacity during first lactation.
paths DS and DD: (n=13) information index traits set 1 + estimated breeding values for weight at first calving and feed intake capacity of her sire and maternal grandsire.

Assumed phenotypic standard deviation, genetic and phenotypic correlations and heritabilities of aggregate genotype and information index traits are given in table 1. Consistency of the parameters was tested by calculation of environmental correlations. All environmental correlation were between -1 and +1. Taking into account the accuracy of estimated breeding values, parameters of table 1 are used to derive variance-covariance matrices (P and G, equation (1)) (Dommerholt, 1984).

### 2.3. Production circumstances and economic values

In this study, 24 alternative situations of production circumstances are considered. The choice of these situations is based on the sensitivity of economic values (Groen, 1989[a], 1989[b]; Groen and Korver, 1989) and practical variation in production circumstances. Situations are grouped according to

*Table 1. Phenotypic standard deviations ($\sigma_P$), heritabilities (diagonal), phenotypic (above diagonal) and genetic correlations (under diagonal) of aggregate genotype and information index traits.*

| trait | $\sigma_P$ | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
|---|---|---|---|---|---|---|---|---|
| 1. milk[1] | 597[i] | .296[i] | .999[i] | .827[i] | .932[i] | .65[iv] | .25[vi] | .25[ii] |
| 2. carrier[1] | 560[i] | .999[i] | .297[i] | .810[i] | .922[i] | .65[iv] | .25[vi] | .25[v] |
| 3. fat[1] | 24.3[i] | .756[i] | .727[i] | .344[i] | .871[i] | .65[iv] | .25[vi] | .25[ii] |
| 4. protein[1] | 18.6[i] | .899[i] | .880[i] | .847[i] | .309[i] | .65[iv] | .25[vi] | .25[ii] |
| 5. fic[2] | 1.9[ii] | .70[iv] | .70[iv] | .70[iv] | .70[iv] | .25[iii] | .38[vi] | .38[ii] |
| 6. mat weight[3] | 45[vi] | .38[vi] | .38[vi] | .38[vi] | .38[vi] | .75[vi] | .50[vi] | .91[vi] |
| 7. weight[4] | 45[iv] | .38[ii] | .38[v] | .38[ii] | .38[ii] | .75[ii] | .91[vi] | .50[iv] |

[1] *305-day lactations yield of a first-parity cow;* [2] *feed intake capacity of first-parity cow;* [3] *mature live weight of a cow;* [4] *weight of a cow at first calving*

*i : Wilmink and De Graaf (1986)*

*ii : Haapa and Syvävärvi (1987)*

*iii: average literature value*

*iv : derived form figures given by Haapa and Syvävärvi (1987) and Miller et al. (1981)*

*v : parameters carrier production are set equal to those for milk*

*vi : parameters mature live weight are set equal to those for weight at first calving and the correlation between these traits chosen to equal correlations of milk production traits in subsequent lactations*

output limitation: no limitation, kilogram milk output limitation or kilogram fat output limitation. Within each group, one basic situation and seven alternative situations are studied. Each alternative situation deviates from the basic situation for a specific circumstance:

(1) milk production level (+ 20% deviation);

(2) roughage quality (energy concent and fill value (extent to which a kg dry-matter of offered roughage takes up dry-matter intake capacity of a reference feed; Groen, 1988); - 10%);

(3) milk prices (carrier, fat and protein prices (+ 10%);

(4) milk protein price (+ 10%);

(5) beef prices (new-born calves and disposed animals; + 10%);

*Table 2. Economic values of aggregate genotype traits in the basic situations ($Dfl.unit^{-1}.cow^{-1}.year^{-1}$)[i].*

| trait | limitation | | |
|---|---|---|---|
| | no | milk | fat |
| carrier | - .13 | - .33 | - .13 |
| fat | 7.97 | 7.75 | 3.04 |
| protein | 11.27 | 11.04 | 11.27 |
| fic[i] | 3.71 | 3.71 | 3.71 |
| live weight | - .92 | - .92 | - .92 |

*i: unit carrier, fat, protein = $kg.lactation^{-1}$; unit feed intake capacity = kg $dry\text{-}matter.day^{-1}$; unit live weight = kg.*

(6) feed prices (prices of roughage and concentrate; - 10%);
(7) price of roughage (- 10%).

Economic values were derived with the model of Groen (1988) and were given by Groen (1989[a], 1989[b]) and Groen and Korver (1989). Economic values for the basis situation are given in table 2. For all other situations, economic values are given in appendix 2.

## 2.4. Cumulative discounted expressions

Cumulative discounted expressions are calculated with a geneflow-programme (Brascamp, 1978). Matrices defining gene transmission and ageing, interest rate and time horizon of evaluation of revenues are equal for all aggregate genotype traits. Incidence vector and additional time adjustment are equal for carrier, fat and protein, but are different for feed intake capacity and live weight.

Matrices defining gene transmission and ageing are defined according to the structure of the Dutch breeding programme given in appendix 1. Initial introduction of genes per selection path was accomplished according to Brascamp (1978).

In discounting future revenues to present day-value an interest rate in real terms (inflation-free) is used (Smith, 1978). The interest rate in real terms (q) equals (Smith, 1978; Luyt, 1985): $q = (r - t)/(1 + t)$, in which

*Table 3. Incidence vectors of aggregate genotype traits used in calculating discounted expressions.*

| | age-class cows | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| trait | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| carrier | .00 | .00 | .25 | .20 | .16 | .13 | .10 | .07 | .05 | .03 | .01 | .003 |
| fat | .00 | .00 | .25 | .20 | .16 | .13 | .10 | .07 | .05 | .03 | .01 | .003 |
| protein | .00 | .00 | .25 | .20 | .16 | .13 | .10 | .07 | .05 | .03 | .01 | .003 |
| fic[i] | .00 | .00 | .25 | .18 | .15 | .12 | .09 | .06 | .04 | .02 | .01 | .002 |
| live weight | .08 | .17 | .20 | .17 | .15 | .12 | .09 | .07 | .04 | .03 | .01 | .003 |

*i: fic = feed intake capacity*

r is the (uncorrected) interest rate and t is the inflation rate. Figures on r and t are drawn from LEI/CBS (1987): 10-year average ('75-'85) of q equals .0385.

In this study, the time horizon for evaluating of revenues of the breeding programme is 25 years.

Incidence vectors account for (a) proportional number of animals within an age class, (b) relative level of expression in an age class and (c) genetic correlation between production within an age class and expression of the age class at which genotype trait is defined (Brascamp, 1973). The proportional numbers of animals are taken from Groen (1988). In this study (b) and (c) are already considered in calculating economic values (Groen, 1988), so the incidence vector carrier, fat and protein includes only aspect (a). The relative levels of expression of feed intake capacity are calculated from levels of exchange in energy intake from concentrate to roughage when increasing genetic merit, as given by Groen and Korver (1989). The relative levels of expression of live weight are calculated from age-dependent live weight of animals at the seventh month after calving (moment of disposal of culled lactating cows; Groen, 1988). Genetic correlation between levels of expression in different age classes for feed intake capacity and live weight are assumed to equal the correlation of milk production traits between first and later lactations (.91; Meyer, 1984). Resulting incidence vectors are given in table 3.

The additional time adjustment discounts revenues from the average moment of expression (in an age-class) to the last day of the age-class. The

*Table 4. Cumulative discounted expressions of aggregate genotype traits per selection path (cow.year.cow$^{-1}$).*

| trait | SS | SD | DS | DD |
|---|---|---|---|---|
| carrier | .217 | .468 | .327 | .745 |
| fat | .217 | .468 | .327 | .745 |
| protein | .217 | .468 | .327 | .745 |
| dmic[i] | .204 | .437 | .306 | .696 |
| mat. weight | .265 | .548 | .390 | .869 |

*i: feed intake capacity*

average moments of expression are assumed to be 140 days for carrier, fat, protein and feed intake capacity and 210 days for live weight. Resulting additional time adjustments are (140-365)/365=-.616 and -.425, respectively.

## 3. RESULTS

Calculated cumulative discounted expressions ($c_{1m}$) are given in table 4. Differences in $c_{1m}$ between aggregate genotype traits arise from different incidences of expression. Differences in $c_{1m}$ between selection paths originate partially from differences between initial moment of gene introduction and the moment of first expression of genes in the population. Table 5 gives the standard deviation of the information index and the correlation between aggregate genotype and information index (per set and selection path in the basis situations). The difference in standard deviation between selection paths SS and SD originates only from differences between cumulative discounted expressions (table 4). The same holds for the difference between selection paths DS and DD. Differences in standard deviation between situations (no, milk or fat output limitation) originate from differences in the absolute levels in economic values between situations (table 4). The correlation between aggregate genotype and information index (per selection path) is hardly influenced by production circumstances.

*Table 5: Standard deviations of information index ($\sigma_I$) and correlation between aggregate genotype and information index ($r_{IH}$) per set of traits and per selection path, in the basic situations.*

| | | limitation | | | | | |
|---|---|---|---|---|---|---|---|
| set | selection | no | | milk | | fat | |
| | path | $\sigma_I$ | $r_{IH}$ | $\sigma_I$ | $r_{IH}$ | $\sigma_I$ | $r_{IH}$ |
| 1 | SS | 38.2 | .93 | 29.0 | .94 | 24.7 | .93 |
| | SD | 82.3 | .93 | 62.7 | .94 | 53.2 | .93 |
| | DS | 42.8 | .69 | 33.5 | .72 | 27.5 | .69 |
| | DD | 97.6 | .69 | 76.4 | .72 | 62.9 | .69 |
| 2 | SS | 36.2 | .92 | 27.4 | .93 | 22.9 | .91 |
| | SD | 78.2 | .92 | 59.4 | .93 | 49.4 | .91 |
| | DS | 37.7 | .64 | 29.5 | .66 | 23.7 | .63 |
| | DD | 86.1 | .64 | 67.3 | .66 | 54.3 | .63 |

### 3.2. Maximum economic revenues

Maximum economic revenues (MER) are obtained when production circumstances considered in defining cattle breeding goals equal actual production circumstances at moments of expression of genetic superiorities. Table 6 gives MER in different situations of production circumstances for set 1 of genotype and index traits.

MER depend to a large extent on the type of output limitation. Imposition of an output limitation will decrease MER by 20 to 40%. Results given by Groen (1988[b]) denote an important decrease in the absolute levels of economic values due to imposition of output limitations. Absolute levels of economic values, through their influence on the standard deviation of the index (see equation (5) and table 5), determine the absolute level of MER. For all types of output limitation, the influences of roughage quality and beef prices on MER are small. Also the influences of milk production level, milk prices and feed prices strongly depend on the type of output limitation. The influences of production circumstances on absolute economic values (Groen, 1989[a], 1989[b]; Groen and Korver, 1989). Groen (1989[b]) denoted a considerable influence of milk production level and roughage price on the economic values of milk production traits in situations with output limitations; in

*Table 6: Maximum economic revenues (MER) of one round of selection in cattle breeding programmes for set 1 (Dfl.cow$^{-1}$).*

| | no limitation | | milk limitation | | fat limitation | |
|---|---|---|---|---|---|---|
| situation | MER | deviation from basis | MER | deviation from basis | MER | deviation from basis |
| basis | 419 | - | 323 | - | 270 | - |
| milk prod. level | 416 | -0.7% | 296 | -8.4% | 225 | -16.7% |
| roughage quality | 418 | -0.2% | 322 | -0.3% | 271 | +0.4% |
| milk prices | 480 | +14.6% | 343 | +6.2% | 272 | +0.8% |
| milk protein pr. | 447 | +6.7% | 328 | +1.5% | 271 | +0.4% |
| beef prices | 419 | 0.0% | 315 | -2.5% | 260 | -3.7% |
| feed prices | 438 | +4.5% | 317 | -1.9% | 251 | -7.0% |
| roughage price | 417 | -0.5% | 304 | -5.9% | 240 | -11.1% |
| no output lim. | - | - | 419 | +29.7% | 419 | +55.2% |
| milk output lim. | 323 | -22.9% | - | - | 323 | +19.2% |
| fat output lim. | 270 | -35.6% | 270 | -16.4% | - | - |

situations without output limitations, milk production level and roughage price hardly influence the economic values of milk production traits (Groen, 1989[a]).

In situations with fat output limitations, an increase in milk protein price will increase the economic value of protein but decrease the economic value of fat (Groen, 1988[b]; see also appendix 2). As a result, the overall influence of milk protein price on MER in situations with fat output limitations is small.

Table 7 gives MER for set 2 of aggregate genotype and information index traits. With a 10% lower roughage price, deviations of MER from the basic situations differ considerably for both sets. This difference originates from the considerable sensitivity of the economic value of feed intake capacity (only included in set 2) towards the price difference between concentrate and roughage (Groen and Korver, 1989). The influences of beef prices on MER remain small, notwithstanding the inclusion of live weight in the aggregate genotype.

*Table 7: Maximum economic revenues (MER) of one round of selection in cattle breeding programmes for set 2 (Dfl.cow$^{-1}$).*

| situation | no limitation MER | no limitation deviation from basis | milk limitation MER | milk limitation deviation from basis | fat limitation MER | fat limitation deviation from basis |
|---|---|---|---|---|---|---|
| basis | 385 | - | 296 | - | 243 | - |
| milk prod. level | 383 | -0.5% | 273 | -7.8% | 198 | -18.5% |
| roughage quality | 384 | -0.3% | 295 | -0.3% | 243 | 0.0% |
| milk prices | 444 | +15.3% | 317 | +7.1% | 244 | +0.4% |
| milk protein pr. | 411 | +6.8% | 301 | +1.7% | 243 | 0.0% |
| beef prices | 387 | +0.5% | 291 | -1.7% | 235 | -3.3% |
| feed prices | 408 | +6.0% | 294 | -0.7% | 229 | -5.8% |
| roughage price | 418 | +8.6% | 305 | +3.0% | 246 | +1.2% |
| no output lim. | - | - | 384 | +30.1% | 385 | +58.4% |
| milk output lim. | 296 | -23.1% | - | - | 296 | +21.8% |
| fat output lim. | 243 | -36.9% | 243 | -17.9% | - | - |

The relative contributions to MER of selection within each selection path are about 20, 37, 33 and 10% for SS, SD, DS and DD, respectively. Relative contributions are hardly influenced by set or situation.

### 3.2. Obtained minus maximum economic revenues

Incorrect prediction of production circumstances when defining cattle breeding goals might lead to losses in economic revenues of cattle breeding programmes. Table 8 gives expected levels of losses in economic revenues in terms of obtained minus maximum economic revenues (OMMER) for set 1 of aggregate genotype and information index traits.

In each group of situations (no, milk or fat output limitation) the basic situation is assumed to represent the predicted production circumstances. So, for example, when in a situation with a milk output limitation the actual milk production level is 20% higher than the predicted milk

*Table 8: Obtained minus maximum economic revenues (OMMER) of one round of selection in cattle breeding programmes for set 1 (Dfl.cow$^{-1}$).*

| | no limitation | | milk limitation | | fat limitation | |
|---|---|---|---|---|---|---|
| actual situation | OMMER | deviation from MER | OMMER | deviation from MER | OMMER | deviation from MER |
| milk prod. level | 0.00 | 0.0% | -2.93 | -1.0% | -0.75 | -0.3% |
| roughage quality | 0.00 | 0.0% | 0.00 | 0.0% | 0.00 | 0.0% |
| milk prices | -0.05 | -0.0% | -4.44 | -1.3% | -0.51 | -0.2% |
| milk protein pr. | -0.13 | -0.0% | -0.39 | -0.1% | -0.54 | -0.2% |
| beef prices | 0.00 | 0.0% | -0.20 | -0.1% | -0.03 | -0.0% |
| feed prices | -0.05 | -0.0% | -0.92 | -0.3% | -0.37 | -0.1% |
| roughage price | 0.00 | 0.0% | -1.38 | -0.5% | -0.30 | -0.1% |
| no output lim. | - | - | -16.57 | -4.0% | -4.26 | -1.0% |
| milk output lim. | -12.76 | -4.0% | - | - | -17.30 | -5.4% |
| fat output lim. | -2.74 | -1.0% | -14.49 | -5.4% | - | - |

production level in the basic situations, there will be a loss in economic revenues of 2.93 (Dfl.cow$^{-1}$), equal to 1.0% of MER (obtained when the higher production level was considered in predicted circumstances).

Incorrect prediction of output limitations will lead to considerable losses in economic revenues (1 to 6% of maximum economic revenues). In absolute terms, these losses equal 2.74 to 17.30 Dfl.cow$^{-1}$.

In situations without limitations, incorrect predictions of production circumstances give rise to small losses in economic revenues. In situations with milk output limitations incorrect predictions of milk production level, milk and roughage prices give rise to losses of 1.38 to 4.44 Dfl.cow$^{-1}$. Milk production level and milk and roughage prices are the production circumstances that most strongly influence relative levels of economic values in situations with milk output limitations (Groen, 1989[b]). In situations with fat output limitations levels of OMMER are small.

Table 9 gives levels of OMMER for set 2. Apparent differences in levels of OMMER between set 1 and set 2 are found for milk production level (in situations with fat output limitations) and roughage price situations. This

*Table 9: Obtained minus maximum economic revenues (OMMER) of one round of selection in cattle breeding programmes for set 2 (Dfl.cow$^{-1}$).*

| | no limitation | | milk limitation | | fat limitation | |
|---|---|---|---|---|---|---|
| actual situation | OMMER | deviation from MER | OMMER | deviation from MER | OMMER | deviation from MER |
| milk prod. level | 0.00 | 0.0% | -3.15 | -1.2% | -2.48 | -1.2% |
| roughage quality | -0.01 | -0.0% | 0.00 | 0.0% | 0.00 | 0.0% |
| milk prices | -0.14 | -0.0% | -1.68 | -0.5% | -0.54 | -0.2% |
| milk protein pr. | -0.15 | -0.0% | -0.39 | -0.1% | -0.58 | -0.2% |
| beef prices | -0.04 | -0.0% | -0.18 | -0.1% | -0.05 | -0.0% |
| feed prices | -0.32 | -0.1% | -0.85 | -0.3% | -0.51 | -0.2% |
| roughage price | -2.11 | -0.5% | -2.26 | -0.7% | -3.07 | -1.2% |
| no output lim. | - | - | -18.65 | -4.9% | -5.87 | -1.5% |
| milk output lim. | -14.35 | -4.9% | - | - | -17.69 | -6.0% |
| fat output lim. | -3.71 | -1.5% | -14.51 | -6.0% | - | - |

difference between set 1 and set 2 originates from the strong influence of milk production level and roughage price on the relative economic value of feed intake capacity (Groen and Korver, 1989).

Relative contributions to OMMER of selection within each path are approximately equal to relative contributions to MER. So, losses in economic revenues due to incorrect prediction of production circumstances result from incorrect selection of animals within all selection paths.

## 4. DISCUSSION

The aim of this study was to quantify influences of production circumstances on economic revenues of cattle breeding programmes. Influences of production circumstances are restricted to influences on economic values of aggregate genotype traits. Influences of other factors, such as genetic potential for genetic improvement (Hazel, 1943), are not considered in this study. A comparable approach as given in this chapter could be used to study

influences of these factors.
In the presented approach, production circumstances have two effects on revenues of breeding programmes: (1) they influence level of maximum economic revenues (MER), considering predicted circumstances to be equal to actual circumstances at the moment of expression of genetic superiorities; (2) they give rise to losses in economic revenues when predicted circumstances are incorrect with regard to actual circumstances (obtained minus maximum economic revenues, OMMER). The sensitivity of MER towards production circumstances denotes which circumstances are of main importance in determining the level of economic revenues of breeding programmes.
The levels of OMMER show levels of losses in economic revenues of breeding programmes when incorrect predictions are made when defining breeding programmes. Therein, levels of OMMER denote the need for adjustments of goals by structural changes in production circumstances. Levels of OMMER denote the need for diversification of breeding goals for different (groups of) farms because of long-term differences in production circumstances. Thereby, levels of OMMER indicate the production circumstances to which farms could be grouped in case of diversification. OMMER might also be used to denote the need for diversification of goals because of uncertainty about future production circumstances (especially prices of products and production-factors).
In calculating OMMER (and MER) it is assumed that actual circumstances are constant during the period in which revenues are obtained. However, prices will change gradually. This implies, that with regard to uncertainty, OMMER gives an upper limit of losses.
Influences of production circumstances on MER and OMMER originate from influences of production circumstances on the absolute and relative levels of economic values, respectively. In this study, influences of specific circumstances are studied separately. In practice, more circumstances can differ simultaneously. For example, there may be a combination of low roughage price and low milk production level ('extensive' production) versus a combination of high roughage price and high milk production level ('intensive'). Additional research showed little differences in economic values of milk production traits for both combinations: the effects of both elements counter-balance. Indications on the extent to which other simultaneous deviations of circumstances influence MER and OMMER can be

drawn from the influences of circumstances on the absolute and relative levels of economic values (Groen, 1988[a], 1988[b]; Groen and Korver, 1989). Changes in specific production circumstances may also be connected with other factors, such as changes in variances; e.g. increase in milk production level gives rise to increase in variance. Such connections were not considered in this study, but may be an issue of future research.
In this study, influences of production circumstances on economic revenues of breeding programmes are quantified for two sets of aggregate genotype traits and information index traits. Both sets are 'dominated' by the strongly correlated milk production traits. As a result, influences of production circumstances on economic revenues are in general comparable for both sets. More research is required to study influences of production circumstances for other sets of aggregate genotype and information index traits, for example a single purpose beef production goal.
Obtained influences of roughage quality are small. In this study only a decrease in roughage quality is studied, as the quality in the basis situation is already rather high. The influence of roughage quality on the economic value of feed intake capacity is non-linear (Groen and Korver, 1989): a decrease in roughage quality increases the economic value only slightly, but an increase in roughage quality strongly decreases the economic value of feed intake capacity. Also influences of milk production level on the economic value of feed intake capacity are non-linear.

## 5. CONCLUSIONS

Sensitivity of MER denotes, that the type of production limitation is of main importance in determining the levels of economic revenues of cattle breeding programmes. From a situation without limitations, imposition of milk and fat output limitations decrease economic revenues by 23% and 36%, respectively. Van Arendonk et al. (1985) also found a reduction in revenues from selection for higher milk yield by about 20% as a result of milk quota.

In situations without limitations, milk prices and feed prices are the main production circumstances to consider in determining levels of economic revenues. In situations with milk output limitations the main circumstances

are milk production level, milk prices and roughage price. In situations with fat output limitations the main circumstances are milk production level and roughage price.
Levels of revenues are important in deciding on (optimum) levels of investment in breeding programmes. Additional studies will have to elucidate the mutual effects of level of investment and structure (for example the percentage of test matings with young bulls) of the breeding programme.

Results on OMMER denote, that incorrect prediction of limitations on product output may lead to losses in economic revenues up to 6% of maximum revenues. For example, in 1984 milk output limitations were introduced in the European countries: no adjustment of the breeding goal to these changed circumstances will decrease revenues of breeding programmes by about 13-15 $\text{Dfl.cow}^{-1}$ per selection round. Predicting a situation without an output limitation while actually a fat output limitation exists, will lead to losses in economic revenues of 3-4 $\text{Dfl.cow}^{-1}$ per selection round.
In situations with milk output limitations, adjustment of cattle breeding goals by breeding organisations is needed when considerable changes in milk production level and milk prices are observed. In situations with fat output limitations, adjustment is needed with changing milk production level and roughage price (the latter only when breeding goals include feed intake capacity).
Breeding goals ought not to change according to seasonal or cyclic variation of production circumstances. But as soon as structural and lasting changes for the important production circumstances are observed, breeding goals should be adjusted in order to avert losses in revenues.

Finally, need for diversification of breeding goals will be discussed. Definition of one common goal by a breeding organisation gives opportunities to obtain large genetic improvement (high selection intensities). However, definition of one common goal, based on average future production circumstances of individual farmers, may lead to losses in revenues because (1) circumstances of individual farmers deviate from average circumstances and (2) future production circumstances cannot be predicted without error. Complete diversification of cattle breeding goals can be carried through by a division of a population or by setting up more nucleus herds (see Nicholas and Smith, 1983). Final conclusions concerning the need for diversification should be based on additional revenues and additional costs of having more breeding goals versus having one breeding goal. The calculation of additional revenues should include:

1. additional revenues when future actual circumstances are known without error and/or when breeding goals match the circumstances of individual farmers;
2. the probabilities of occurrence of different situations of production circumstances;
3. time-span needed for a replacement of genes within the population.

The calculation of additional costs should include:

1. additional costs of maintaining and selecting more breeds;
2. reduction in economic revenues due to decreased selection intensities.

Smith (1985) studied the costs and revenues of selecting many breeding stocks of a species. He calculated additional revenues of an increase in number of stocks (aspect (1) calculation of revenues) from a decrease in risk factor included in the interest rate for discounting future revenues. Assuming a risk factor equal to an (inflation and risk free) interest rate (2.5%), Smith (1985) obtained proportional additional revenues up to a maximum of 25% of revenues from selection within one stock, assuming an evaluation period of 20 years. This alternative required 20 to 60 different stocks. The levels of OMMER derived in this study also denote additional levels of economic revenues when actual circumstances are known: they do not exceed 6% of the maximum economic revenues. Smith (1985) only included marginal costs of maintaining and selecting additional breeds. He concluded that having a large number of alternative stocks is justified. However, assumptions made by Smith (1985), especially on the level of risk factor and the marginal costs of additional stocks, possibly gave an over-estimation of benefits of having a large number of stocks.
As pointed out, OMMER gives only one aspect of the determination of the need for diversification of breeding programmes. The levels of OMMER for incorrect prediction of output limitations are 1.0 to 6.0%. Levels of OMMER for incorrect prediction of other circumstances (milk production level, milk prices, feed prices and roughage quality) are 0.0 to 1.3%. These levels of OMMER are, at least for reasons other than differences in output

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**Appendix 1.** *Structure of the breeding programme. Structure corresponds to the situation of the total Dutch dairy cattle population in 1986-1987. Most figures are drawn from NRS (1988).*

- number of (average present) cows = 2 000 000
- number of cows in active breeding population = 1 488 000 (74.4% of the cows is recorded for milk production)
- total number of 1st-inseminations: 1 832 600 (1.1 1st-insemination per cow; 83.3% use of A.I.)
- 9.2% of 1st-inseminations with sperm of beef bulls
- 23% of 1st-inseminations with sperm of young bulls (YB) for progeny testing (450 YB, 960 1e-inseminations each)
- 68.8% of 1st-inseminations with sperm of proven bulls = 1 232 000
- culling of cows and proven bulls for other reasons than index = 20%
- proven bulls are used 3.25 years and have 12 700 1e-insem. per year --> annually 1 232 000/(12 700*3.25*.8) = 37.5 proven bulls selected on index
- bull sires are used 3.00 years and have 10 sons tested --> annually 450/(10*3*.8) = 18.75 bull sires selected on index
- probability of having a bull calf per bull dam = .4 or 1.0 without and with embryo transfer, respectively
- 50% application of embryo transfer with bull dams
- 50% of the YB are disposed during rearing period (e.g. ilness, fertility)
- in order to obtain 450 YB to be progeny tested, 450/(.8*(.5*1+.5*.4)*.5) = 1607 bull dams selected on index
- 60% of the female calves born are needed for replacement within the herd
- the relative partition of sire and dams over age-classes of bulls and cows, respectively is as follows (9 age-classes for bulls and 12 for cows; partition of dams to breed dams is taken from Groen (1988)):

| selection | age-class | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| path | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| SS | .00 | .00 | .00 | .00 | .00 | .20 | .40 | .30 | .10 | - | - | - |
| YB + SD | .00 | .23 | .00 | .00 | .00 | .20 | .25 | .20 | .12 | - | - | - |
| DS | .00 | .20 | .30 | .30 | .20 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| DD | .00 | .25 | .20 | .26 | .13 | .10 | .07 | .05 | .03 | .01 | .01 | .00 |

**selection intensities:**

SS from YB = 18.75 outof 450 --> $i_{SS}$ = 2.135

SD from YB = 37.50 outof 450 --> $i_{SD}$ = 1.842

DS from active cow population 1607 outof 1 488 000 --> $i_{DS}$ = 3.367

DD 60%/.8 of total population --> $i_{DD}$ = .424

**Appendix 2.** *Economic values (Dfl.cow$^{-1}$.year$^{-1}$.unit$^{-1}$) (Groen, 1989[a], 1989[b]; Groen and Korver, 1989).*

| limitation | alternative | deviation | carrier | fat | protein | feed int.cap. | live weight |
|---|---|---|---|---|---|---|---|
| no | basis | - | - .13 | 7.97 | 11.27 | 3.71 | - .92 |
| | milk prod. level | + 20% | - .13 | 7.91 | 11.23 | 4.63 | - .92 |
| | roughage quality | - 10% | - .13 | 7.96 | 11.27 | 3.90 | - .93 |
| | milk prices | + 10% | - .13 | 9.07 | 12.59 | 3.71 | - .92 |
| | milk protein pr. | + 10% | - .13 | 7.97 | 12.59 | 3.71 | - .92 |
| | beef prices | + 10% | - .13 | 7.97 | 11.27 | 3.71 | - .83 |
| | feed prices | - 10% | - .12 | 8.28 | 11.47 | 3.71 | - .73 |
| | roughage price | - 10% | - .13 | 7.94 | 11.25 | 22.26 | - .55 |
| milk | basis | - | - .33 | 7.75 | 11.04 | 3.71 | - .92 |
| | milk prod. level | + 20% | - .40 | 7.62 | 10.94 | 4.63 | - .92 |
| | roughage quality | - 10% | - .33 | 7.74 | 11.04 | 3.90 | - .93 |
| | milk prices | + 10% | - .43 | 8.76 | 12.27 | 3.71 | - .92 |
| | milk protein pr. | + 10% | - .38 | 7.68 | 12.30 | 3.71 | - .92 |
| | beef prices | + 10% | - .35 | 7.73 | 11.03 | 3.71 | - .83 |
| | feed prices | - 10% | - .38 | 8.00 | 11.18 | 3.71 | - .73 |
| | roughage price | - 10% | - .38 | 7.68 | 10.98 | 22.26 | - .55 |
| fat | basis | - | - .13 | 3.04 | 11.27 | 3.71 | - .92 |
| | milk prod. level | + 20% | - .13 | 1.51 | 11.23 | 4.63 | - .92 |
| | roughage quality | - 10% | - .13 | 3.06 | 11.27 | 3.90 | - .93 |
| | milk prices | + 10% | - .13 | 2.10 | 12.59 | 3.71 | - .92 |
| | milk protein pr. | + 10% | - .13 | 2.06 | 12.59 | 3.71 | - .92 |
| | beef prices | + 10% | - .13 | 2.71 | 11.27 | 3.71 | - .83 |
| | feed prices | - 10% | - .12 | 2.05 | 11.47 | 3.71 | - .73 |
| | roughage price | - 10% | - .13 | 2.03 | 11.25 | 22.26 | - .55 |

## General discussion

This research project was started to study:

- the methodology of deriving economic values;
- the economic values of milk production traits, beef production traits, feed intake capacity;
- the extent to which production circumstances influence economic values of genetic improvement.

The methodology of deriving economic values is discussed in chapter one and six. Chapter two describes the model used to derive the economic values of milk production traits (carrier, fat and protein), beef production traits (birth weight and mature weight) and feed intake capacity. Results on the influences of production circumstances on the economic values are given in chapter three, four and five. A study on the relationship between breeding goals and production circumstances should determine:

- the important production circumstances in defining breeding goals and calculating revenues of breeding programmes;
- the need for adjustment of breeding goals when structural and lasting changes in production circumstances occur;
- the need for diversification of breeding goals because of heterogenity of and uncertainty about future production circumstances.

Chapter seven gives the results and the conclusions on these aspects.

In each chapter of this thesis, main results have been discussed. This general discussion will be confined to:

1. additional aspects of methodology of deriving economic values;
2. extension of traits and production circumstances.

### Methodology

The 'economic value' of a trait expresses to what extent economic efficiency of production is improved at the moment of expression of one unit genetic superiority of that trait. The 'cumulative discounted expression' of a trait reflects time and frequency of future expression of a superior genotype originating from the use of a selected individual in a breeding programme. Multiplication of the economic value by the cumulative discounted expression gives the 'discounted economic value' (chapter seven). Discounted economic values are used to:

1. aggregate genotypes for several traits to a so called 'aggregate genotype' which is used as a concrete breeding goal;
2. value predicted genetic superiorities in a breeding programme in order to calculate economic revenues of this programme.

The relative levels of discounted economic values of traits are of main concern for an accurate definition of the breeding goal, giving optimum levels of genetic improvement according to the future state of production circumstances. For an accurate calculation of the level of economic revenues of breeding programmes (in order to optimize the structure of the programme), mainly the absolute levels of economic values are important. Genetic improvement is an area of technical development, and long term effects of implementation of new techniques will be, among others, change in market prices (Cochrane, 1958). Future changes in market prices due to genetic improvement might rather influence absolute levels than relative levels of discounted economic values. Omission of changes in future prices, especially decreases in product prices, in deriving economic values, might cause over-estimation of the revenues of breeding programmes. So, especially when discounted economic values are used to calculate economic revenues of breeding programmes, their derivation should include future changes in market prices. The dynamics of future changes in market prices might be included in deriving economic values by modelling at sector or national level (chapter one).

Mathematical programming techniques might be included in deriving economic values to:

1. optimize management of production systems, for example replacement policy in dairy cattle, delivery weight of veal calves;
2. determine values of production-factors for an individual production system.

In chapter one, the inclusion of mathematical programming techniques, to optimize management of production systems with regard to production circumstances (including levels of genetic merit), in deriving economic values was discussed. Sensitivity of economic values toward differences in herd composition, originating from differences in replacement policy, was discussed in chapter three. Differences in herd composition resulted in different marginal output levels of new-born calves and adult cows when

increasing genetic merit for birth weight and mature weight, respectively. It was concluded that via optimization of the replacement policy, beef prices have additional indirect affects on economic values of beef production traits. In this example of the optimization of replacement policy, indirect effects were small relative to direct effects of beef prices. For general recommendations on the inclusion of mathematical programming techniques to optimize management in deriving economic values, more examples are to be studied.
Mathematical programming techniques, especially linear programming, might be used to determine farm specific values of production-factors such as labour and roughage. In this study, prices of products and production-factors are considered to be exogeneous parameters for the individual farms. Results of this study denote, on the one hand, that there is no need to study the value of production-factors for different types of farms, by means of linear programming models, in order to distinguish between types for a diversification of the cattle breeding goal. However, on the other hand, linear programming techniques might be useful to determine the absolute levels of revenues of genetic improvement for a specific type of farm.

The choice of a perspective in production, including interest of selection and base of evaluation, has been discussed in chapter six. In this general discussion, one additional aspect of the concepts in deriving economic values will be discussed: the planning term. The choice of a planning term should be included in deriving economic values regarding:
- the choice of (exogeneous) price parameters;
- the distinction between variable and fixed costs.
In this study, a strategic planning is used to distinguish between variable and fixed costs. All costs are considered to be variable in time; fixed costs included only costs that are fixed with respect to the size of the farm (chapters three and six). The strategic planning term is chosen, because in cattle breeding future expression of genetic superiority originating from a selected animal will mainly be more than five years after the moment of selection of this animal. Two comments on this choice are to be made:
1. it is problematic to distinguish between a strategic and tactical term in estimating future price parameters;

2. some traits, for example beef production traits related to new-born calves, will be expressed within two years.

This latter aspect requires additional study on the influences of the planning term on cattle breeding goals.

In this research project, a deterministic and static bio-economic model is used to derive economic values. The modelling objective was to study the behaviour of the system as a reaction on a change in the state of endogeneous elements representing genetic merit of the animals. The deterministic way of modelling is chosen, for the main objective was to study differences in behaviour in relation to the state of elements representing production circumstances of the system; not to study the possibilities of behaviour given a certain state of production circumstances, which would require a stochastic model.

The model is static in the sense that it studies the behaviour for a one-year time period, being the moment in which a superior genetic merit is expressed. Inclusion of price changes when modelling at sector level would require a dynamic model.

**Traits and production circumstances**

Main quenstions raised in building the model used in this study concerned the simulation of (1) energy requirement for growth and maintenance of young replacement stock and (2) dry-matter intake capacity of lactating cows. Future research might provide a deeper understanding on qualitative and quantitative relations for both areas mentioned.

Further to these observations, absence of relevant technical data seems to be a main hindrance for an accurate derivation of economic values of, for example, body and carcass characteristics and susceptibility for diseases. According to Emanuelson (1988), the economic value of genetic improvement of susceptibility of diseases ought to include: production losses, veterinary and labour costs, replacement costs, detrimental affects on quality of products, market acceptance and consumer views. Mougham and Verstegen (1988) presented a generalized biological model of nutrient flow in the growing pig. Growth simulation models give the opportunity (1) to assign basic biological parameters as beef production traits which might be included in the breeding goal and (2) to calculate accurately average and

marginal costs of beef production traits and improvement of these traits, respectively. To include susceptibility for diseases, and body and carcass traits in the breeding goal, with an accurate weighing relative to milk production traits, more research on the economic values and relevant technical data is wanted.
The production circumstances considered in this study are: input and output limitations, product and production-factor prices, production levels, herd composition and roughage quality. Economic values of studied traits are found to be mainly sensitive to production circumstances that (1) determine the possible use of production-factors saved due to genetic improvement or (2) determine the value of production-factors for a given use. These conclusions drawn on studied traits may well be generalized for other traits, since the principles of valuation of production-factors in deriving economic values are equal for all traits.
Literature provides evidence that the implementation of new techniques might influence economic values, e.g. reproduction techniques (Groen et al., 1988) and bovine somatotropine (Groen, unpublished data). Thereby, new techniques offer new possibilities of measuring new traits or to reduce cost of measurement of traits, e.g. field data on carcass composition (Henningson, 1987) and on feed intake of dairy and beef cattle (Jackson et al., 1987). State of technology is a part of the economic production circumstances that determine organisation and efficiency of cattle production systems. Additional research is wanted to study the influences of implementation of new techniques on cattle breeding goals.

In practice, specific combinations of elements of natural, social and economic production circumstances occur for countries, regions or farms, giving rise to more or less specific definition of the cattle breeding goal. On one hand, this study provides general discussions and conclusions on the relationship between cattle breeding goals and production circumstances. On the other hand, this study provides basic knowledge on methodology to be used in specific practical definition of cattle breeding goals, especially the derivation of economic values.

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**Summary**

This thesis gives the results of a study on the relationship between cattle breeding goals and production circumstances. The relationship between breeding goals and production circumstances mostly arises from the influences of production circumstances on the economic values of genetic improvement of animal traits. The economic value of a trait expresses to what extent economic efficiency of production is improved at the moment of expression of one unit genetic superiority of that trait. Economic values are used in defining the breeding goal (to aggregate genotypes for several traits to a so called 'aggregate genotype') and also in calculating economic revenues of breeding programmes (to value predicted genetic superiorities).
The objects of this project are to study:

- the **methodology** of deriving economic values;
- the **economic values** of milk production traits, beef production traits and feed intake capacity of lactating cows;
- the extent to which **production circumstances** influence economic values.

Further to the latter object, three issues are to be discussed:

- the important production circumstances in defining breeding goals and calculating revenues of breeding programmes;
- the need for adjustment of breeding goals when structural and lasting changes in production circumstances occur;
- the need for diversification of breeding goals because of heterogenity of and uncertainty about future production circumstances.

**Methodology**

The choice of a methodology of deriving economic values includes choices on five aspects:

1. an economic versus a biological definition of efficiency;
2. an interest of selection: maximize profit, minimize cost price or maximize revenues on investment;
3. the definition of the production system:
   - level: animal, farm or national,
   - size or base of evaluation: fixed number of animals, fixed input of a production-factor or fixed output of a product;
4. the planning term: strategic or tactical;

5. the method: positive or normative approach, the latter including efficiency equations and bio-economic modelling.

Literature on these aspects is reviewed in chapter one. In chapter six, the concepts of economic production theory for different perspectives (combinations of interests of selection and bases of evaluation) are given. These concepts are derived by elaboration of the influences of genetic improvement on costs and revenues, using general equations on costs and revenues of a dairy farm.

In this study, efficiency of production is considered to be economic efficiency as money is the standard for measuring value.

Concepts of economic production theory denote that derivation of economic values according to a specific perspective implicitely assumes a certain use of production-factors saved due to genetic improvement. Consequently, economic values derived according to different perspectives will differ when values of production-factors differ between alternative uses. However, imposition of three conditions will lead to equal values of production-factors and to equivalence of perspectives. These conditions are: (1) one-product situation or revenues of other products are negative costs, (2) equilibrium in a purely competitive industry, and (3) all costs are variable per unit product. Applicability of these conditions in now-a-days agricultural industry is limited. Practically, the individual producer's interest of selection has to be chosen, which is profit maximization, for the individual producer is the principal decision-maker in animal breeding. In general, the production circumstances, imposed by governments or the individual producer's situation, will determine the practical choice of a base of evaluation.

Genetic improvement is an area of technical development, and long term effects of implementation of new techniques will be, among others, change in market prices. To include these future price changes, the theoretically appropriate level to be used in deriving economic values is the national level. In this study, modelling at farm level is used, allowing acquirement of basic knowledge on the sensitivity of economic values towards production circumstances.

The choice of a planning term should be included in deriving economic values regarding (1) the choice of (exogeneous) price parameters and (2) the distinction between variable and fixed costs. In this study, a strategic planning is used: all costs are considered to be variable in time, fixed costs include only costs that are fixed with respect to the size of the farm.

Derivation of economic values concerns (1) quantification of the levels of changes in physical amounts of inputs and outputs of the system as a result of a change in genetic merit, and (2) valuation of these changes in physical amounts. In this study, bio-economic modelling (using multi-equation models) is used to derive economic values. This offered good opportunities to consider a large number of elements and relationships in both quantification and valuation of changes in physical amounts.

**Economic values**

Chapter two describes the dairy farm model used to derive economic values of milk and beef production traits and feed intake capacity. This static and deterministic model describes quantitative relationships between levels of genetic merit for the considered traits and levels of inputs and outputs of the farm, in relation to production circumstances. Inputs and outputs of the farm are calculated from feed costs, labour cost, costs of buildings and other variable and fixed costs, and revenues of selling milk and animals (beef). Intake of roughage and concentrate by lactating cows is based on the ratio between energy requirement and dry-matter intake capacity. Improvement of genetic merit of milk and beef production traits results in increase in milk and beef revenues per animal, respectively, and in increase in feed costs per animal. The economic value of feed intake capacity is derived assuming that increase in feed intake capacity allows for a cheaper composition of energy intake (an exchange from concentrate to roughage intake; chapter five). In the basic situation, the economic values of carrier, fat and protein are -.13, 7.97 and 11.27, respectively; the economic values of birth weight and mature weight are 7.35 and -.92; the economic value of feed intake capacity is 3.71 $Dfl^{-1}.cow^{-1}.year^{-1}.kg^{-1}$.

**Production circumstances**

Chapter three and four give the results on the sensitivity of economic values of milk and beef production traits towards production circumstances in situations without and with limitations, respectively. Chapter five deals with the results on the sensitivity of the economic value of feed intake

The type of output limitation is of main importance in determining the levels of economic revenues of cattle breeding programmes. Compared with a situation without limitations, imposition of milk and fat output limitations decrease revenues by 23 and 36%, respectively. In situations without limitations, milk prices and feed prices are the main circumstances to consider in determining levels of economic revenues. In situations with milk output limitations the main circumstances are milk production level, milk prices and roughage price. In situations with fat output limitations the main circumstances are milk production level and roughage price.
Predicting a situation without an output limitation while actually a milk or fat output limitation exists, will lead to losses in economic revenues of 13-15 or 3-4 $Dfl.cow^{-1}$ per selection round, respectively. In situations with milk output limitations, adjustment of cattle breeding goals by breeding organisations is needed when considerable changes in milk production level and milk prices are observed. In situations with fat output limitations, adjustment is needed with changing milk production level and roughage price.
Incorrect prediction of limitations on product output may lead to losses in economic revenues from 1 to 6% of maximum revenues. Losses for incorrect prediction of other circumstances (milk production level, milk prices, feed prices and roughage quality) are 0.0 to 1.3%. These levels of losses are, at least for reasons other than differences in output limitations, too low to justify complete diversification of dairy breeding goals within a cattle breeding programme. Future research on diversification of cattle breeding goals, including aspects of costs, should focuss on differences in output limitations, as a different circumstance between groups of farms or as an uncertain production circumstance.

# SAMENVATTING

Dit proefschrift geeft de resultaten van een onderzoek naar de samenhang tussen het fokdoel in de rundveefokkerij en de produktie-omstandigheden. De samenhang tussen fokdoel en produktie-omstandigheden komt met name voort uit de invloed van de produktie-omstandigheden op de zogenaamde 'economische waarden' van genetische verbetering van dierkenmerken. Deze economische waarden brengen de mate van verbetering van de efficiëntie van produktie bij expressie van één eenheid genetische superioriteit tot uitdrukking. De economische waarden worden enerzijds gebruikt bij de definitie van het fokdoel (bij het aggregeren van de genetische aanleg voor diverse kenmerken tot een fokdoel, het 'aggregate genotype') en anderzijds bij de berekening van opbrengsten van een fokprogramma (bij het waarderen van verwachte danwel gerealiseerde genetische vooruitgang voor de diverse kenmerken). De doelstellingen van dit onderzoek zijn de bestudering van:

- de methodiek die gebruikt dient te worden bij de berekening van economische waarden;
- de berekening van economische waarden voor melk- en vleesproduktiekenmerken, alsmede voeropnamecapaciteit van melkgevende dieren;
- de mate waarin economische waarden beïnvloed worden door produktie-omstandigheden.

Aansluitend op de laatste doelstelling worden drie onderwerpen besproken:

- de produktie-omstandigheden die het meest van invloed zijn op de definitie van het fokdoel en het niveau van de opbrengsten van fokprogramma's;
- de noodzaak tot een aanpassing van fokdoelen wanneer zich structurele en blijvende veranderingen in de produktie-omstandigheden voordoen;
- de noodzaak tot opsplitsing van fokdoelen, gegeven dat produktie-omstandigheden verschillen tussen (groepen van) bedrijven en dat toekomstige produktie-omstandigheden niet zondermeer bekend zijn.

## Methodiek

De keuze van een methodiek ter berekening van economische waarden omvat keuzes voor een vijftal aspecten:

1. de wijze waarop efficiëntie van produktie wordt uitgedrukt: biologische of economische efficiëntie;
2. het belang, de doelstelling van selektie: winst-maximalisering, kost-

prijs-minimalisering of maximalisering van de opbrengsten per eenheid kosten;

3. de definitie van het systeem:
   - niveau: dier, bedrijf of land;
   - omvang of uitgangspunt van evaluatie: vast aantal dieren, vaste input van een produktiefaktor of vaste output van een produkt;
4. de termijn van planning, dat wil zeggen, de termijn waarop de genetische verbetering gerealiseerd wordt: strategische (over meer dan vijf jaar) of tactische (over één à twee jaar);
5. de methode zelf: positieve of normatieve systeem analyse, waarbij de laatste de mogelijkheden van enkelvoudige vergelijkingen en omvangrijke bio-economische modellering omvat.

Hoofdstuk één geeft een overzicht van de literatuur die ingaat op deze vijf aspecten. Hoofdstuk zes gaat in op de principes binnen de economische produktie-theorie zoals die gelden voor verschillende perspectieven (combinaties van enerzijds het belang van selektie en anderzijds het uitgangspunt van evaluatie, zoals die hierboven zijn aangegeven). Deze principes zijn afgeleid door middel van een uitwerking van de effecten van genetische verbetering op kosten en opbrengsten, gebruikmakende van algemene formules voor de kosten en opbrengsten van een melkveehouderijbedrijf.
Gezien het feit dat geld 'de standaard' is voor het aangeven van de waarde van goederen en diensten is in deze studie efficiëntie gedefinieerd als economische efficiëntie.
De afgeleide principes binnen de economische produktie-theorie geven aan dat een keuze van een perspectief in feite de aanwending van produktiefaktoren, die vrijkomen bij verbetering van de genetische aanleg, bepaalt. Daardoor zullen economische waarden, bepaald volgens verschillende perspectieven, verschillen wanneer de waarden van produktiefaktoren binnen diverse aanwendingsmogelijkheden uiteenlopen. Wanneer aan de berekening van economische waarden drie randvoorwaarden worden verbonden, zullen de waarden van produktiefaktoren binnen diverse aanwendingsmogelijkheden gelijk zijn en zullen, derhalve, perspectieven equivalent zijn. De bedoelde randvoorwaarden zijn: (1) een één-produkt-situatie danwel berekening van een netto-kostprijs, (2) een evenwichtssituatie binnen een zuivere markt van volledige mededinging, (3) alle kosten zijn variabel per eenheid produkt. Over het algemeen zullen deze randvoorwaarden niet van toepassing zijn

binnen de huidige agrarische produktie. Praktisch gezien is de individuele veehouder degene die de keuzes met betrekking tot selektie van dieren maakt. De doelstelling van de individuele veehouder, zijnde winst-maximalisering, zal dan ook de keuze van het belang van selektie moeten zijn. De keuze van een uitgangspunt van evaluatie zal bepaald worden door overheidsmaatregelen danwel de praktische situaties van bedrijven.
Genetische verbetering is een toepassingsgebied van technologische vernieuwing. Op de lange termijn zal het gebruik van nieuwe technieken leiden tot, ondere andere, veranderingen in marktprijzen. Modellering op nationaal niveau is het geeigende niveau om deze prijsveranderingen in de berekening van economische waarden mee te kunnen nemen. In deze studie is echter gemodelleerd op bedrijfsniveau, omdat dit niveau ook goede mogelijkheden biedt tot het verkrijgen van basiskennis over de invloeden van produktie-omstandigheden op de economische waarden.
De keuze van een planningstermijn dient tot uitdrukking te komen in (1) de keuze van (exogene) prijsparameters en (2) het te maken onderscheid tussen variabele en vaste kosten. In deze studie is uitgegaan van een strategische termijn. Dat wil zeggen, alle kosten worden geacht variabel te zijn over tijd; de vaste kosten bevatten alleen de kosten die, ongeacht de omvang van het bedrijf, constant zijn.
Berekening van economische waarden behelst (1) kwantificeren van de fysieke veranderingen in inputs en outputs van het systeem alsgevolg van veranderingen in de genetische aanleg, en (2) waardering van deze fysieke veranderingen. Voor deze studie is gekozen voor een vorm van bio-economische modellering (gebruik makende van modellen met meerdere vergelijkingen), omdat deze wijze van modellering goede mogelijkheden biedt tot het in beschouwing nemen van een groot aantal elementen en relaties bij zowel de kwantificering alswel de waardering van fysieke veranderingen.

**Economische waarden**

Hoofdstuk twee beschrijft het voor de berekening van economische waarden opgestelde en gebruikte model van een melkveehouderijbedrijf. Dit statische en deterministische model beschrijft kwantitatieve relaties tussen niveaus van genetische aanleg voor de beschouwde kenmerken en niveaus van inputs en outputs van het bedrijf, in relatie tot de produktie-omstandigheden. Inputs en outputs van het bedrijf omvatten de voerkosten, arbeidskosten, kosten van gebouwen en andere variabele en vaste kosten, en de opbrengsten van verkoop van melk en dieren (vlees). Het rantsoen van de melkgevende dieren, in de zin van de verhouding tussen ruwvoer en krachtvoer, wordt binnen het model berekend aan de hand van de verhouding tussen de energiebehoefte en de voeropnamecapaciteit van de dieren. Verbetering van de genetische aanleg voor melk- en vleesproduktiekenmerken resulteert enerzijds in een verhoging van respectievelijk de melk- en vleesopbrengsten per dier, en anderzijds in een verhoging van de voerkosten per dier. De economische waarde van voeropnamecapaciteit is afgeleid, aannemende dat een toename van de voeropnamecapaciteit de mogelijkheid geeft voor een goedkopere samenstelling van het rantsoen (een uitwisseling van krachtvoer naar ruwvoer). In de veronderstelde basissituatie zijn de berekende economische waarden van drager, vet en eiwit respectievelijk -.13, 7.97 en 11.27; de economische waarden van geboortegewicht en volwassengewicht 7.35 en -.92; de economische waarde voor voeropnamecapaciteit 3.71 $fl.koe^{-1}.jaar^{-1}.kg^{-1}$.

**Produktie-omstandigheden**

In de hoofdstukken drie en vier zijn de resultaten met betrekking tot de gevoeligheid van economische waarden van melk- en vleesproduktiekenmerken voor verschillen in produktie-omstandigheden gegeven, en wel voor respectievelijk situaties zonder en met beperkingen. Hoofdstuk 5 geeft de resultaten voor het kenmerk voeropnamecapaciteit. De produktie-omstandigheden die in deze studie zijn meegenomen, zijn: beperkingen op input van produktiefaktoren of output van produkten, prijzen van produkten en produktiefaktoren, produktieniveaus, veestapelsamenstelling en voerkwaliteit.

Algemene stelregel is, dat economische waarden gevoelig zijn voor die produktie-omstandigheden die (1) de aanwendingsmogelijkheden van, de door genetische verbetering vrijgekomen produktiefaktoren bepalen danwel (2) de waarde van vrijgekomen produktiefaktoren binnen een zekere aanwendingsmogelijkheid bepalen. In situaties zonder beperkingen zijn de prijzen van produkten en produktiefaktoren van doorslaggevend belang voor het niveau van de economische waarden van melk- en vleesproduktiekenmerken. Produktieniveaus en voerkwaliteit hebben in situaties zonder beperkingen geen noemenswaardige invloed op de economische waarden van melk- en vleesproduktiekenmerken. Het belangrijkste gevolg van het instellen van een beperking op melkproduktie-omvang van het bedrijf is een verlaging van de economische waarde van drager. Instelling van een inputbeperking op ruwvoer resulteert met name in een verlaging van de economische waarden van vleesproduktiekenmerken ten opzicht van de economische waarden van melkproduktiekenmerken. Enkelvoudige outputbeperkingen hebben belangrijke gevolgen voor de relatieve niveaus van economische waarden van de produktiekenmerken. In situaties met beperkingen zijn de economische waarden van de produktiekenmerken gevoelig voor prijzen van produkten en produktiefaktoren alsmede niveau van melkproduktie en volwassengewicht. De economische waarde van voeropnamecapaciteit is zeer gevoelig voor voerfaktoren (m.n. voerkwaliteit) en dierfaktoren (m.n. produktieniveaus) die de voeropname van melkgevende dieren beïnvloeden. Bovendien is de economische waarde van voeropnamecapaciteit in sterke mate afhankelijk van het prijsverschil tussen ruwvoer en krachtvoer.

De aangegeven gevoeligheid van economische waarden heeft een tweetal gevolgen voor de economische opbrengsten van fokprogramma's. Ten eerste is het niveau van de opbrengsten van fokprogramma's afhankelijk van de produktie-omstandigheden. Ten tweede kunnen foutieve aannames ten aanzien van de produktie-omstandigheden waaronder de toekomstige genetische verbetering tot expressie zal komen, leiden tot foutieve definitie van het fokdoel en daarmee tot een derving in opbrengsten. In hoofdstuk zeven worden beide gevolgen gekwantificeerd voor een tweetal sets van fokdoelkenmerken (met melkproduktiekenmerken, volwassengewicht en voeropnamecapaciteit) en voor 24 situaties van produktie-omstandigheden (waaronder produktiebeperkingen, melkproduktieniveau, energiegehalte van ruwvoer en prijzen van produkten en produktiefaktoren). De in deze studie aangenomen struktuur van het fokprogramma komt in grote lijnen overeen met de situatie van de totale Nederlandse melkveestapel.
Uit de resultaten blijkt dat het type produktiebeperking in belangrijke mate het niveau van de opbrengsten van fokprogramma's bepaald. Nemen we als uitgangspunt een situatie zonder beperkingen, dan zal instelling van een melk- of vetproduktiebeperking leiden tot een verlaging van het niveau van de opbrengsten van respectievelijk 23 en 36%. In situaties zonder beperkingen zijn de melkprijzen en de voerprijzen de belangrijkste omstandigheden die het niveau van de opbrengsten van fokprogramma's bepalen.

In situaties met een melkproduktiebeperking zijn de belangrijkste omstandigheden het melkproduktieniveau en de melk- en voerprijzen. In situaties met een vetproduktiebeperking zijn de belangrijkste omstandigheden het melkproduktieniveau en de ruwvoerprijs.

Wordt bij de definitie van het fokdoel aangenomen dat er geen produktiebeperking zal zijn op het moment dat de verbeterde genetische aanleg tot expressie komt, terwijl er op dat moment in werkelijkheid wel een beperking op melk- danwel vetproduktie is, dan leiden deze foutieve aannames tot een derving aan opbrengsten van respectievelijk 13-15 en 3-4 $fl.koe^{-1}$ per selektieronde. In situaties met een melkproduktiebeperking is aanpassing van het rundveefokdoel noodzakelijk wanneer zich wijzigingen voordoen in het melkproduktieniveau of de melkprijzen. In situaties met een vetproduktiebeperking is aanpassing noodzakelijk bij veranderingen in melkproduktieniveau of ruwvoerprijs.

Foutieve aannames met betrekking tot beperkingen leiden tot een derving van 1 tot 6% van de maximale opbrengsten. Foutieve aannames met betrekking tot andere produktie-omstandigheden (melkproduktieniveau, melkprijzen, voerprijzen en voerkwaliteit) zorgen voor een derving van 0,0 tot 1,3%. Deze niveaus van derving in opbrengsten zijn, in elk geval voor redenen anders dan verschillen in produktiebeperkingen, te laag om een opsplitsing van het fokdoel binnen een fokkerij-organisatie te rechtvaardigen. Toekomstig onderzoek naar de noodzaak tot opsplitsing van fokdoelen zal zich moeten richten op de produktiebeperking als zijnde een omstandigheid die kan verschillen tussen groepen van bedrijven, danwel een omstandigheid waarvoor de toekomst niet zondermeer vaststaat. Een dergelijk onderzoek zal zowel kosten als opbrengsten van het nastreven van meerdere fokdoelen in ogenschouw moeten nemen.

## Curriculum vitae

Ab Groen werd op 28 augustus 1962 geboren te 's Gravenhage. Op 3-jarige leeftijd verhuisde hij naar Holten waar hij verder opgroeide en het lager onderwijs volgde. Hij behaalde in 1980 het Atheneum-diploma aan het Christelijk Lyceum te Almelo. In september van dat jaar begon hij aan zijn studie aan de Landbouwhogeschool te Wageningen. Het doctoraalexamen Zoötechniek, met als hoofdvakken Veeteelt en Gezondheids- en Ziekteleer en als bijvak Optimaliseringstechnieken, werd cum laude afgelegd in januari 1986. Per 1 februari 1986 werd hij als promotie-assistent aangesteld bij de vakgroepen Agrarische Bedrijfseconomie en Veefokkerij van de huidige Landbouwuniversiteit. Vanaf 1 december 1988 is hij als universitair docent werkzaam bij de vakgroep Agrarische Bedrijfseconomie.