User's Manual for the Program Package ECOWEIGHT (C Programs for Calculating Economic Weights in Livestock), Version 5.0.1. Part 1: Programs EWBC (Version 2.1.2) and EWDC (Version 2.0.4) for Cattle

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February 11, 2010

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Preface

The program package ECOWEIGHT was written within the framework of the research projects MZE-M02-99-02 and MZE0002701401 that were supported by the Ministry of Agriculture of the Czech Republic. In the Slovak Republic, financial support was given by the Ministry of Agriculture within the framework of the research projects 2003 SP 27/028 OD 02/028 OD 02 and 2006 UO27/0910502/0910517. Travelling was funded by the Ministries of Education of the Czech Republic and Slovak Republic (Program KONTAKT, project numbers 109CZ/2002 or 198SK/2002 and MEB 080802 or SK-CZ-0007-07).

The programs for cattle were mainly written by Jochen Wolf on the base of algorithms prepared by Marie Wolfová (both from the Institute of Animal Science in Prague Uhříněves). Parts of the programs were written by Emil Krupa from the Slovak Center of Agricultural Research in Nitra.

Though only three people were engaged directly in writing the program, a lot of colleagues has helped in different ways in preparing the algorithm for the program. Radka Zahrádková and Josef Přibyl (both Prague-Uhříněves) have given advises concerning the management systems. Josef Přibyl has furthermore made available information on the breeding value estimation and on selection programs in cattle. Jan Kica and Jozef Daňo from the Slovak Center of Agricultural Research in Nitra cooperated in the fields of nutrient requirement and economics, respectively.

Furthermore, thanks are due to Jindřich Kvapilík and Václav Teslík from the Institute of Animal Science in Prague-Uhříněves for their help in obtaining mainly the economic and management input parameters. Daniel Bureš from the same Institute and Josef Golda† from the Research Institute for Cattle Breeding in Rapotín have extended the data for carcass classification of cattle on the base of the SEUROP system. Stanislav Hejduk from the Mendel University of Agricultural and Forestry Brno has made available information about the nutrition value of pasture and Karel Šeba from the Beef Breeders Association of the Czech Republic has made comments on beef cattle breeding and testing. Last but not least, the technical assistance of Petra Mrázková (Prague-Uhříněves) is acknowledged.

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Chapter 1

Introduction

The program package ECOWEIGHT is intended for the calculation of economic values of economically important traits in livestock. At the given stage, in its fifth version, two programs for cattle and three programs for sheep are available (see Table 1.1). The two programs for cattle (EWBC and EWDC) are described in the present part of the documentation which is the first part of the manual. The second part of the program package is a stand-alone program (EWSH1) for sheep with one lambing per year [16]. The third part of the program package which is documented in two manuals is formed by the program EWSH2 for sheep [17] which is a modification of EWSH1 and by the program GFSH [15] which models gene flow in sheep. As the programs EWSH2 and GFSH are run together they are in a joint installation package.

Table 1.1: Survey on the program package ECOWEIGHT, version 5.0.1

Part[a]	Installation Package[b]	Program(s)	Species, remarks
01	ECOWEIGHT01_5_0_1.tgz	EWBC	beef cattle
		EWDC	dairy cattle
02	ECOWEIGHT02_5_0_1.tgz	EWSH1	sheep, one lambing per year, stand-alone program
03A	ECOWEIGHT03_5_0_1.tgz for both parts 03A and 03B	EWSH2	sheep, one lambing per year, used in combination with GFSH
03B		GFSH	sheep, program for gene flow, used in combination with EWSH2

[a]There is one manual for each part; its name is ECOWEIGHT[part].pdf where [part] is to be replaced by the two or three digits given in this column.
[b]Replace 'tgz' by 'zip' for Windows.

Several pasture production systems for beef cattle without production limitation and the dairy production system applying terminal crossing with beef bulls are treated with in the two programs EWBC and EWDC. Economic values can be calculated for beef and dairy cattle. Pure-bred dairy production systems without terminal crossing and without production limitation or with milk and fat quota can be handled.

The inclusion of the gene-flow procedure makes it possible to calculate relative economic weights for maternal and direct components of traits as well as for different selection paths. These weights are intended to be used for the construction of

selection indices to evaluate breeding animals (in beef cattle above all for bulls and bull dams). A survey of cattle production systems currently covered by the program is given in Figure 1.1.

Besides this, the program will be useful for some economic analyses in different production systems. The impact of production, management and economic circumstances on the economic efficiency of a given production system can be studied.

The users of the programs EWBC and EWDC are recommended to read the papers of Wolfová et al. published 2005 in Livestock Production Science [22, 23] and 2007 in the Journal of Dairy Science [20, 21] which describe the basic theory underlying the program and show applications. Furthermore, we recommend the paper of Wolfová and Nitter [18] where the number of discounted expressions are discussed.

At the given stage, the program EWBC is restricted to systems with winter and early spring calving before the pasture season. Problems may occur when using the program on the southern hemisphere. You can overcome these problems in a simple way: add to all dates in INPUT01.TXT half a year and everything should work correctly. We are aware of this problem. During the following development of the program package, we intend to make the program for beef cattle run for arbitrary calving date within the year. Furthermore, we would like to include in-door systems for beef cattle.

Version 5.0.1 of the program package ECOWEIGHT contains version 2.0.4 of the EWDC program and version 2.1.2 of the EWBC program.

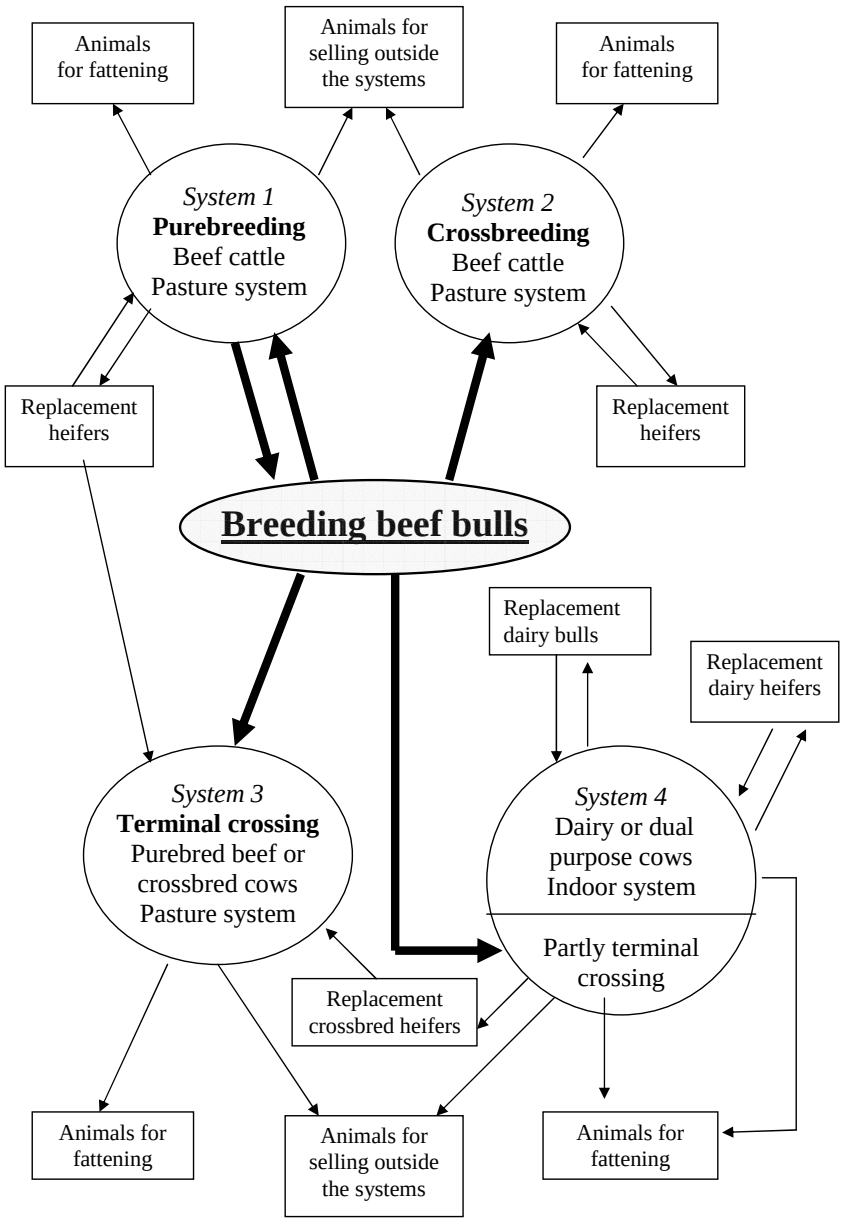

Figure 1.1: Production systems in cattle

Chapter 2

Basic description of the bio-economic model

A bio-economic model is used to describe the four main production systems in cattle (Fig. 1.1). The first three systems are beef production systems based on a cow-calf pasture system with integrated intensive (indoor) or extensive (on pasture) fattening. The fourth system is a traditional dairy production system with dairy cow herds and integrated intensive fattening. The possibility to do no fattening but to sell all weaned calves or breeding bulls and heifers outside the system (export) is also given.

The model includes both deterministic and stochastic components. Most performances of animals are simulated as herd averages, but phenotypic variation in carcass quality (described by the distribution over commercial classes), in milk production and weight of heifers at mating (described by mean and standard deviation) are included. The model is non-integer (fractions of animals are allowed) and the cow herd size is given by a fixed number of cows entering the calving season in the pasture system or by a fixed number of cow calving per year in the dairy system. Only when applying limitations to the input of production factors or outputs of products the number of cows is rescaled when calculating the economic weights. For the basic features of the model see also [22]. An application of the model to production systems with the Charolais breed in given in [23].

2.1 Production systems

2.1.1 Cow-calf pasture systems (Production Systems 1 to 3)

These systems are run by the program EWBC. The management of the beef cow-calf production systems is modelled according to the typical situation in Central Europe. The reproductive cycle of cows is determined by the seasons in temperate climate. Calves are born in the winter period (in the Northern hemisphere usually from November to March) and weaned all at the same date. The length of the pasture period depends on the climatic conditions (the begin and the end of the pasture period are input parameters and can be freely chosen). In Central Europe, pasture is mostly available from the beginning of May to the end of October or November. The model can be applied also for beef cattle production systems in the tropics, if no more than two nutrition periods per year are distinguished or can be simulated (e.g. dry and wet periods will correspond to winter and summer periods in temperate climate).

All females (heifers and cows) are mated to beef bulls. The breeding season is

held at constant length covering three oestrus cycles of females. One oestrus cycle is assumed to last 20 days. In the pure-bred beef herds producing breeding animals, the mating starts usually with artificial insemination by sperm of top-bulls. After the insemination period, a break in the mating is made with a length of about one weak. This is necessary for the identification of calves born after insemination. Natural mating follows on the pasture. In commercial herds that produce calves for fattening, only natural mating is used in most cases. The user of the present program has the opportunity to define his own mating policy. Exclusively insemination or natural mating can be used throughout. The fractions of inseminated heifers and cows of the animals entering the mating period can be freely chosen. But the total length of the mating period should not exceed the length of three oestrus cycles to minimise the variability in the age of weaned calves. The length of the reproductive cycle is assumed to be fixed to one year. The average date of conception of all females in the herd as well as the average date at calving and at weaning is calculated on the base of a assumed conception rate (input parameter) in each oestrus cycle within the mating period.

Weaned calves are utilised according to the replacement policy for the herd. Three possible policies are included in the model. They are designated as Production Systems 1 to 3.

- *Production System 1* includes pure-bred beef herds that produce breeding heifers for its own replacement and eventually for sale, and breeding bulls (performance-tested on station or in the field) for replacement in all connected systems.
- *Production System 2* are beef herds with cross-breeding that produce breeding heifers for its own replacement and eventually for sale but purchase sperm for artificial insemination and/or the breeding bulls for natural mating (e.g. rotational crossing).
- *Production System 3* includes herds that purchase pure-bred or cross-bred replacement heifers and bulls or sperm for terminal crossing.

For all these systems, integrated fattening of excessive progeny is generally assumed, but the possibility to sale weaned calves outside the systems (for export) is also given. The sale of breeding heifers in Systems 1 or 2 is allowed only if the number of reared heifers exceed the number of heifers needed for own replacement. The number of the production system and several options connected with the production system are input parameters in the file PARA.TXT - see Section 4.1.2.

All male and female calves not sold and not needed as replacements are fattened as heifers, bulls or castrates. The proportion of fattened castrates from the male weaned calves is chosen by the user. Two possible fattening systems are included in the model: (i) intensive fattening indoor or (ii) extensive fattening on pasture (for heifers and castrates only). Fattening is performed to a fixed optimal slaughter weight that depends on the maturity type of the animals (that means on the breed of cows and the breed of bulls used for mating). The optimal slaughter weight of cross-bred animals is calculated as the average of the optimal slaughter weight of the parental breeds.

Replacement heifers are put on the same regime as cows and are bred according to the breed type that determines the optimal weight at breeding. The weight of heifers at first breeding is assumed to follow a normal distribution whose parameters (mean and standard deviation) are input parameters in the file INPUT13.TXT (see Section 4.2.10). This procedure allows to calculate the fraction of heifers of the late maturity type (i.e. from breeds as French Charolais, which are assumed to be bred

circa at an age of two years) which can be mated already at an age of approximately one year. This fraction depends on the growth rate from birth to mating.

Heifers and cows not pregnant after the mating period are generally slaughtered after the finishing period on the pasture. The possibility to stay to the next mating period for non-pregnant females with a high breeding value is included in the model. A maximum of three mating periods is allowed. The number of reproductive cycles per cow is an input parameter in the parameter file PARA.TXT (see Section 4.1.2). A value of approximately 15 should be a reasonable choice in most cases, as only a very small fraction of cows is assumed to have more than 15 reproductive cycles. Values lower than 4 or greater than 20 are not allowed. Each of these cycles can be described separately through inserting the appropriate input parameters for the calving performance, losses of cows and calves, culling of cows due health problems or no pregnancy and the proportion of insemination. It is assumed that performance-tested bulls are possession of the herd owners. Therefore, costs of testing and revenues from selling breeding bulls as well as from culling negatively selected bulls are part of the herd profit.

The performance test of bulls is assumed to be of fixed length. Selected bulls are sold to the insemination stations or to the herd that uses them for natural mating. Bulls not selected are slaughtered. The selected bulls are expected to be progeny tested in the field. In the controlled herds, the progeny is weighed four times: at birth and usually at the age of about 120, 210 and 365 days. These weights and ages are used for the calculation of daily gain of calves in different growth periods in the model. The age of calves at individual weighings (growth periods) are variables in the program and can be controlled by the user.

2.1.2 Dairy production system (Production System 4)

This system is run by the program EWDC. A classical indoor production system with dairy or dual purpose cows producing milk with integrated intensive indoor fattening is handled in the model. The calving is assumed to be equally distributed over the whole year. A rate of artificial insemination of 100% is assumed. Cows not pregnant after a fixed number of inseminations are culled at the end of the lactation. Maximally 15 lactations for a cow are included in the model. The maximal number of lactions is a input parameter in the file PARAD.TXT (see Section 4.1.3 on page 51) Each of these lactations can be described separately through inserting the appropriate input parameters as described for the pasture system (see Section 2.1.1).

A part of the cow herd can be inseminated with sperm of beef bulls to improve the fattening performance of progeny. Cows with low milk production are used for this crossing.

All born calves are reared together under equal conditins until reaching a given fixed age. Selling reared calves outside the system (export) is possible. Pure-bred heifers for replacement are mated at an optimal weight for the given breed, so that their age at mating depends on the growth rate in the previous period. Heifers not pregnant after a fixed number of inseminations are slaughtered after a given number of days. Cross-bred females can be finished to a fixed slaughter weight, sold outside the system (export) or transferred (sold) as replacement heifers to a joined or separate cow-calf Production System 3.

Pure-bred male calves for replacement are performance tested on station. Selected bulls are sold to the insemination stations and the animals not selected are slaughtered. Breeding male calves are sold to the test station at a certain age (3 months in Czechia). Therefore, only costs and revenues for breeding male calves till their selling to the test station are included in the calculation of the profit. All remaining cross-bred progeny and the excessive pure-bred progeny are fattened to

a fixed optimal slaughter weight that depends on the maturity type of the progeny (that means on the breed of the parents).

The dairy production system can be handled independently of the beef production systems as a pure-bred system without terminal crossing and can be used to calculate economic weights for traits of dairy cattle. In this special case, the input parameters that give the proportion of terminal crossing in individual lactations in input file INPUT07.TXT (see on page 72) must be set to zeros.

2.2 Structure of the cow herd

For calculating the structure of the cow herd, different categories of animals were defined. The number of the reproductive cycles is an input parameter (LL) which is expected to be in the range from 4 to 15 (program EWDC) or to 20 (program EWBC). Low numbers of LL may cause problems as the cow herd might not be able to produce sufficient replacement.

Categories distinguished are related to the reproductive cycles of cows that cover the intervals between two subsequent calvings. A replacement female enters the herd at her calving and can stay in the herd until she is replaced or has reached the maximum of allowable calvings. Each category is characterised as a combination of two variables: *the number of the reproductive cycle* r ($r = 1, ..., LL$) and the defined *stage* s the cow is in within the given reproductive cycle ($s = 1, ..., 6$ for $r < LL$ or $s = 1, ...4$ for $r = LL$). The total number of cow categories (TT) is therefore

$$TT = 6(LL - 1) + 4 \; . \tag{2.1}$$

There are 24 categories of progeny defined (see below) and the numbering of categories starts with the progeny which takes numbers 1 to 24. Thus the appropriate cow category i ($i = 25, ..., CC$) for given r and s is:

$$i = 6(r + 3) + s \tag{2.2}$$

where $CC = TT + 24$. That means, CC is the total number of animal categories in Systems 1 to 3. In System 4, all categories of progeny may occur as pure-bred or as cross-bred categories. Therefore, the number of progeny categories is 48 and the total number of categories CT is calculated as $CT = TT + 48$. See below for the numbering of the categories. The six stages for cows are defined as given in Section 2.2.2.3. Just a short comment to the formula given here. This formula has no deeper sense, it is just a practical solution how to calculate i for the (fully arbitrary) system of numbering categories of animals used in the present program.

The cow herd structure in all systems was derived using Markov chains. The herd dynamics was described in terms of categories animals can belong to and probabilities of possible transitions between these categories. The procedure is similar to those described by Jalvingh et al. [6] or Reinsch and Dempfle [9]. Let $\mathbf{T}$ be the quadratic transition matrix of dimension TT with elements t_{ij} being the probability that an animal changes in a given time unit Δt from category i to category j (Δt can be i.g. the length of the reproductive cycle). Assume further that $\mathbf{c}^{[t]}$ is the row vector with elements being the probability that an animal belongs to category i at time t. Then the same vector at time $t + \Delta t$, $\mathbf{c}^{[t+\Delta t]}$, is calculated as:

$$\mathbf{c}^{[t+\Delta t]} = \mathbf{c}^{[t]}\mathbf{T} \tag{2.3}$$

For $t \to \infty$, the Markov chain reaches its stationary state, that means the difference $\mathbf{c}^{[t+\Delta t]} - \mathbf{c}^{[t]}$ converges to zero. In the program, the stationary state is calculated by an iteration procedure. For more details see Wolfová et al. [22].

2.2.1 Definition of reproductive cycles

A maximal number of LL calvings per cow is assumed (LL is in the interval from 4 to 20 in systems 1 to 3 or from 4 to 15 in System 4). On this basis, the following LL reproductive cycles are defined:

1	Cows between 1st and 2nd calving
2	Cows between 2nd and 3rd calving
3	...
...	...
$LL-1$	Cows between $(LL-1)$th and LLth calving
LL	Cows from LLth calving to slaughter

2.2.2 Definition of categories of animals

2.2.2.1 Categories of progeny

There are 24 categories of pure-bred progeny which are numbered from 1 to 24. In several of the categories, subcategories are formed in Systems 1 to 3 (program EWBC) which are numbered from $CC+1$ to $CC+10$ (see below). In program EWDC (System 4), all 24 categories of progeny may occur also as cross-bred animals. The cross-bred categories are numbered from $CC+1$ to CT ($CT = CC+24$). That means if the pure-bred category has number i ($i = 1, ..., 24$), then the appropriate category of cross-bred animals has number $CC+i$.

1	Still born calves of both sexes (including aborts)
2	Calves of both sexes which died during 48 hours after birth
3	Calves of both sexes which died from 2 days of age till weaning (beef cattle) or the end of the rearing period (dairy cattle)
4	Bulls which died within the fattening period (from birth to death)
5	Castrates which died in the fattening period (from birth to death)
6	Heifers which died in the fattening period (from birth to death)
7	Heifers for replacement which died from weaning (beef cattle) or from the end of the rearing period (dairy cattle) to entering the cow herd (from birth to death)
8	Female calves sold at weaning (beef cattle) or at the end of the rearing period (dairy cattle)
9	Male calves sold at weaning (beef cattle) or at the end of the rearing period (dairy cattle)
10	Bulls transmitted or sold to the test stations and selected as breeding animals (from birth to selling)
11	Bulls transmitted or sold to the test stations and slaughtered after the test (from birth to slaughter)
12	Fattened heifers (from birth to slaughter)

13 Fattened heifers slaughtered due to health problems before reaching the slaughter weight (from birth to slaughter)

14 Fattened bulls (from birth to slaughter)

15 Fattened bulls slaughtered before reaching slaughter weight due to health problems (from birth to slaughter)

16 Fattened castrates slaughtered before reaching slaughter weight due to health problems (from birth to slaughter)

17 Fattened castrates (from birth to slaughter)

18 Heifers for replacement selected before first mating and slaughtered (from birth to the age of female at first mating)

19 Heifers for replacement slaughtered after the mating periods because of lack of pregnancy (from birth to the age at mating plus time to slaughter)

20 Heifers purchased for herd replacement (for Production System 3 always, for Systems 1 to 2 and 4 only if not enough female animals are reared and pregnant for herd replacement)

21 Program EWBC (Systems 1 to 3): empty category (not defined), Program EWDC (System 4): reserved for veal calves in a later version of the program (not used yet in the present version)

22 Heifers for replacement conceived in the mating periods and entered the first reproductive cycle (from birth to 1st calving)

23 Breeding heifers sold to other production systems before mating

24 Pregnant heifers sold to other production systems

In Production Systems 1 to 3 (program EWBC), subcategories were defined for several categories of heifers (see on page 15). The subcategories for category 19 are:

$CC + 1$ Heifers slaughtered after the first mating period

$CC + 2$ Heifers slaughtered after the second mating period

$CC + 3$ Heifers slaughtered after the third mating period

The subcategories for category 22 are:

$CC + 4$ Heifers conceived in the first mating period

$CC + 5$ Heifers conceived in the second mating period

$CC + 6$ Heifers conceived in the third mating period

The subcategories for category 23 are:

$CC + 7$ Heifers sold before the first mating period

$CC + 8$ Heifers sold before the second mating period

The subcategories for category 24 are:

$CC + 9$ Pregnant heifers sold after the first mating period

$CC + 10$ Pregnant heifers sold after the second mating period

2.2.2.2 Categories of cows (or developmental stages) within reproductive cycle r ($r = 1, ..., LL - 1$)

$19 + 6r$ Cows died within the reproductive cycle (stage 1)

$20 + 6r$ Cows culled between calving and mating period due to health problems after dystocia[1] (stage 2)

$21 + 6r$ Cows culled within the reproductive cycle due to health problems other than dystocia. In System 4, this category includes cows culled for low milk production. (stage 3)

$22 + 6r$ Cows culled after weaning calves (or after lactation in Production System 4) because of lack of pregnancy (stage 4)

$23 + 6r$ In Production Systems 1 to 3 (program EWBC): not pregnant cows entering the next reproductive cycle (only cows with high breeding value); empty category in program EWDC - Production System 4 (stage 5)

$24 + 6r$ Pregnant cows entering the next reproductive cycle (stage 6)

2.2.2.3 Categories of cows (or developmental stages) within reproductive cycle LL

$19 + 6LL$ Cows died within the reproductive cycle (stage 1)

$20 + 6LL$ Cows culled between calving and mating period due to health problems after dystocia (stage 2)

$21 + 6LL$ Cows culled within the reproductive cycle due to health problems other than dystocia. In System 4 (program EWDC), this category includes cows culled for low milk production. (stage 3)

$22 + 6LL$ Cows culled after weaning calves (or after lactation in Production System 4) (stage 4)

2.3 Lactation curve

In Production Systems 1 to 3 (program EWBC), the Wood function is used for the description of the lactation curve. Its general form looks like this [24]:

$$MP(t) = a(t + C)^b exp(-c(t + C)) \tag{2.4}$$

where $MP(t)$ is the milk yield at day t of lactation, a, b, c are parameters and C is a constant. The value 14 was inserted for C [4].

If the parameters a, b, c are available, they can be inserted in the input file INPUT20.TXT (see Section 4.2.16 on page 71). Option 1 should be chosen in the file PARA.TXT (see Section 4.1.1.7). Otherwise option 2 should be chosen for the parameters of the lactation curve. The estimation of the parameters is then carried out as given in the subsequent section.

In System 4 (program EWDC), a further modification of the Wood function proposed by Fox et al. [4] and taking into account days in pregnancy was used:

$$MP(t) = at^b exp(-ct) exp(-dp) \tag{2.5}$$

where a, b, c and d are parameters and p are days in pregnancy. A simple way for a rough calculation of the parameters is given in Section 2.3.2 on the next page.

[1] For the definition of dystocia see paragraph 2.6.3.1 on page 32.

2.3.1 Calculation of the parameters of the lactation curve in program EWBC (for Production Systems 1 to 3)

The coefficients of the lactation curve are estimated according to the procedure of Fox et al. [4]. In case that there is sufficient information available, parameters directly estimated from lactation data can be inserted in the program. This option is controlled by a parameter in the input file PARA.TXT (see Section 4.1.2).

The concept of Fox et al. [4] is based on the peak milk yield of a mature cow (M_{pm0}) of the given breed on the average production level. For the production level itself (PL) values between 1 and 9 are allowed, 1 representing the lowest, 5 the average and 9 the highest production level, respectively. The peak milk yield for a mature cow (M_{pm}) on production level PL is then calculated as

$$M_{pm} = (0.125PL + 0.375)M_{pm0} \tag{2.6}$$

The peak milk yields for cows being two, three or four years old which are assumed to be on the first, second and third lactations, respectively, are:

$$M_{p2} = 0.6M_{pm}, \quad M_{p3} = 0.825M_{pm}, \quad M_{p4} = 0.925M_{pm}. \tag{2.7}$$

Mature cows are supposed to reach the peak milk yield after $LM_m = M_{pm} + 40$ days of lactation. The appropriate values for two, three and four year old cows are:

$$LM_2 = LM_m + 10, \quad LM_3 = LM_m - 10, \quad LM_4 = LM_m - 5. \tag{2.8}$$

The coefficient a of the Wood function is for two, three, four year old and mature cows, respectively:

$$\begin{aligned} a_2 &= (4.0 - 0.05LM_2)M_{p2}/k_2 \quad \text{with} \quad k_2 = 6 \\ a_3 &= (6.65 - 0.11LM_3M_{p3}/k_3 \quad \text{with} \quad k_3 = 8.25 \\ a_4 &= (5.85 - 0.09LM_4)M_{p4}/k_4 \quad \text{with} \quad k_4 = 9.25 \\ a_m &= (5.3 - 0.075LM_m)M_{pm}/k_m \quad \text{with} \quad k_m = 10 \end{aligned} \tag{2.9}$$

For the given values of k_2, k_3, k_4 and k_m is

$$M_{p2}/k_2 = M_{p3}/k_3 = M_{p4}/k_4 = M_{pm}/k_m = M_{pm}/10 \tag{2.10}$$

The appropriate coefficients b and c for the Wood function are:

$$\begin{aligned} b_i &= \frac{\ln M_{pi} - \ln a_i}{\ln(LM_i + 14) - 1} \\ c_i &= \frac{b_i}{LM_i + 14} \end{aligned} \tag{2.11}$$

with index i in both equations taking the values 2, 3, 4 or m.

2.3.2 Calculation of the parameters of the lactation curve in program EWDC (for Production System 4)

In the present version of the program, parameter values according to Fox et al. [4] are used. Parameter a is calculated from the average yearly milk production per cow (YMP) as follows:

$$a = (0.01YMP - 20 \times 0.454)/2.96 \tag{2.12}$$

for the first lactation and

$$a = (0.01YMP + 14 \times 0.454)/2.96 \tag{2.13}$$

for the second and subsequent lactations.
The constant 0.454 not contained in the original equations of Fox et al. [4] is the conversion constant between lb and kg. Please have in mind that in the present program the unit kg is used throughout.

Parameter b is set to 0.08, 0.12 and 0.16 for the 1st, 2nd, 3rd and subsequent lactations, respectively. Parameter c takes values -0.002, -.004 and -0.005 for the 1st, 2nd, 3rd and subsequent lactations, respectively, and parameter d is -0.001 for the 1st lactation and -0,002 for the 2nd and subsequent lactations. All these values are taken from [4] and are contained as default values in the input file INPUT22.TXT (Section 4.3.6 on page 81).

2.4 Calculation of daily net energy and protein requirements per animal

2.4.1 Calves from birth to 3 months of age (energy and protein requirements for growth and maintenance)

The average daily net energy (NE) and protein (PDI) requirements are calculated as follows [11]:

$NE = -2.67 + 0.4184W^{0.75} + 5.6854ADG + 1.7526ADG^2$ [in MJ NE/day]

$PDI = -8.88 + 3.2527W^{0.75} + 274.4842ADG - 16.5273ADG^2$ [in g/day]

where W is weight in kg at the given day and ADG is average daily gain for the given period in kg/day.

2.4.2 Calves from 3 months of age to weaning (beef cattle) or to the end of the rearing period (dairy cattle): Growth and maintenance

The following equations for energy and protein requirements were proposed by Petrikovič and Sommer [8]:

$NE = 0.570W^{0.75}(0.530 + 0.400ADG)$ [in MJ NE/day]

$PDI = 3.25W^{0.75} + (220.50 + 0.976W^{0.75})ADG$ [in g/day]

2.4.3 Fattened heifers (growth and maintenance)

Equations according to Sommer et al. [11] (the first equation for NE refers to heifers of the beef type, the second equation for NE is valid for heifers of the dairy type):

$NE = k_{he}(0.348k_tW^{0.75} + 0.004W^{1.3} + 5.584ADG^2)$ [in MJ NE/day]

$NE = k_{he}(0.35k_tW^{0.75} + 0.0022W^{1.4} + 7.254ADG^{1.75})$ [in MJ NE/day]

$PDI = k_{hp}(3.25W^{0.75} + 0.147W + 216.3ADG - 5)$ [in g/day]

where k_{he} is a correction coefficient for energy requirement of heifers referring to their maturity type, k_t is a correction coefficient for housing technology and k_{hp} is a correction coefficient for protein requirement of heifers referring to their maturity type.

2.4.4 Fattened bulls (growth and maintenance)

All equations were derived by Petrikovič and Sommer [8].

Equations for bulls of dairy type:

$NE = (0.34k_t + 0.25ADG)W^{0.75}$ [in MJ NE/day]

$PDI = 3.25W^{0.75} + (220 + 0.70W^{0.75})ADG$ [in g/day]

Equations for bulls of dual purpose type:

$NE = 0.34k_tW^{0.75} + (2.5 + 0.16W^{0.75})ADG$ [in MJ NE/day]
$PDI = 3.25W^{0.75} + (220 + 0.85W^{0.75})ADG$ [in g/day]

Equations for bulls of beef type:

$NE = 0.34k_tW^{0.75} + (3.0 + 0.13W^{0.75})ADG$ [in MJ NE/day]
$PDI = 3.25W^{0.75} + (220 + 0.975W^{0.75})ADG$ [in g/day]

2.4.5 Fattened castrates (growth and maintenance)

Equations according to Petrikovič and Sommer [8]:

$NE = k_{ce}W^{0.75}(0.34k_t + 0.275ADG)$ [in MJ NE/day]
$PDI = k_{cp}[3.25W^{0.75} + (220 + 1.050W^{0.75})ADG]$ [in g/day]

where k_{ce} and k_{cp} are correction coefficients for energy requirement and protein requirement, respectively, of castrates referring to their maturity type.

2.4.6 Replacement heifers from weaning (beef cattle) or from the end of the rearing period (dairy cattle) to calving (growth, maintenance and pregnancy)

Equations according to Petrikovič and Sommer [8]:

Heifers of dairy type:

$NE = 0.587W^{0.75}(0.53k_t + 0.445ADG) + NE_p$ [in MJ NE/day]
$PDI = 3.25W^{0.75} + (220.5 + 0.976W^{0.75})ADG + PDI_p$ [in g/day]

where NE_p and PDI_p are the additional daily net energy and protein requirements, respectively, caused by pregnancy. They are calculated as in Section 2.4.8.

Heifers of dual purpose type:

$NE = 0.580W^{0.75}(0.53k_t + 0.415ADG) + NE_p$ [in MJ NE/day]
$PDI = 3.25W^{0.75} + (220.5 + 0.976W^{0.75})ADG + PDI_p$ [in g/day]

Heifers of beef type:

$NE = 0.570W^{0.75}(0.53k_t + 0.400ADG) + NE_p$ [in MJ NE/day]
$PDI = 3.25W^{0.75} + (220.5 + 0.976W^{0.75})ADG + PDI_p$ [in g/day]

2.4.7 Replacement breeding bulls from weaning (beef cattle) or from the end of the rearing period (dairy cattle) to mature weight (growth and maintenance)

The same equations as for fattened bulls were used until bulls reached mature weight (see Section 2.4.4). The net energy and protein requirements for maintenance after reaching mature body weight were calculated as follows [11]:

$NE = 14.35 + 0.044W$ [in MJ NE/day]
$PDI = 153 + 0.511W$ [in g/day]

2.4.8 Cows (growth, maintenance, pregnancy and lactation)

The overall daily net energy and digestible protein requirements for cows were assumed to be:

$NE = k_tk_bNE_m + NE_g + NE_l + NE_p$ [in MJ NE/day]
$PDI = PDI_m + PDI_g + PDI_l + PDI_p$ [in g/day]

where k_b is a correction coefficient for breed, k_t is a correction coefficient for housing technology, NE_m, NE_g, NE_l and NE_p are the daily net energy requirements for maintenance, growth, lactation and pregnancy, respectively, PDI_m, PDI_g, PDI_l and PDI_p are the appropriate terms for digestible protein requirements.

The energy and protein requirements for maintenance and growth were calculated as [13]:

$NE_m = 0.293W^{0.75}$ [in MJ NE/day]
$PDI_m = 3.25W^{0.75}$ [in g/day]
$NE_g = 22ADG$ [in MJ NE/day]
$PDI_g = 230ADG$ [in g/day]

The energy and protein requirements for lactation were estimated from the daily milk production corrected for a fat and protein content [8]:

$NE_l = MP(0.95 + 0.37fat + 0.21prot + 0.07)$ [in MJ NE/day]
$PDI_l = 6.7 + 1.05fat + 11.5prot$ [in g/day]

where MP is the daily milk production with the milk fat percentage fat and milk protein percentage $prot$. The calculation of the daily milk production is treated with in Section 2.3.

The energy and protein requirements for pregnancy were calculated as follows [12]:

$NE_p = 0.0024116BW(0.4504-0.000766d_p)e^{(0.03233-0.0000275d_p)d_p}$ [in MJ NE/day]
$PDI_p = 1.64*6.25BW(0.001669-0.00000211d_p)e^{(0.0278-0.0000176d_p)d_p}$ [in g/day]

where BW is the birth weight of calves in kg and d_p is the duration of pregnancy in days. The coefficient 1.64 transforms the net protein values originally calculated in [12] into PDI values.

2.4.9 Examples for feed rations and their energy and protein content

Several examples for feed rations and their energy and protein content (for the Charolais breed) are given in Tables 2.1 to 2.8 (see pages 23 to 25).

Table 2.1: Example for energy and protein content in feed rations for cows

	Feed ration		Price	Dry matter	Net energy	Protein
	Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Summer	Pasture	1.00	*0.25*	*0.20*	*6.15*	*95.1*
Winter	Lucerne hay	0.30	0.70	0.85	5.07	112.4
	Corn silage	0.58	0.50	0.24	6.13	58.9
	Mashed barley	0.12	3.10	0.91	8.25	92.4
	Total	1.00	*0.87*	*0.50*	*6.06*	*93.2*

DM: dry matter, Kč: Czech currency unit, 1 euro is about 30 Kč.

Table 2.2: Example for energy and protein content in feed rations for calves till weaning if milk yield is insufficient

	Feed ration		Price	Dry matter	Net energy	Protein
	Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Summer	Pasture	0.67	0.25	0.20	6.15	95.1
	Mashed oats	0.33	2.50	0.88	7.45	86.2
	Total	1.00	*1.03*	*0.42*	*7.04*	*89.0*
Winter	Mashed oats	1.00	*2.50*	*0.88*	*7.45*	*86.2*

Table 2.3: Example for energy and protein content in feed rations for heifers from weaning to calving

	Feed ration		Price	Dry matter	Net energy	Protein
	Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Summer	Pasture	1.00	*0.25*	*0.20*	*6.15*	*95.1*
Winter	Lucerne hay	0.18	0.70	0.85	5.07	112.4
	Corn silage	0.78	0.50	0.24	6.13	58.9
	Mashed barley	0.04	3.10	0.91	8.25	92.4
	Total	1.00	*0.64*	*0.38*	5.91	83.8

Table 2.4: Example for energy and protein content in feed rations for breeding bulls for natural mating

	Feed ration		Price	Dry matter	Net energy	Protein
	Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Summer	Pasture	1.00	*0.25*	*0.20*	*6.15*	*95.1*
Winter	Lucerne hay	0.10	0.70	0.85	5.07	112.4
	Mashed oats	0.14	2.50	0.88	7.45	86.2
	Corn silage	0.73	0.50	0.24	6.13	58.9
	Wheat straw	0.03	0.20	0.87	3.15	24.3
	Total	1.00	*0.79*	*0.41*	*6.12*	*74.5*

Table 2.5: Example for energy and protein content in feed rations for heifers and castrates in extensive fattening

	Feed ration		Price	Dry matter	Net energy	Protein
	Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Summer	Pasture	1.00	*0.25*	*0.20*	*6.15*	*95.1*
Winter after weaning	Lucerne hay	0.18	0.70	0.85	5.07	112.4
	Corn silage	0.78	0.50	0.24	6.13	58.9
	Mashed barley	0.04	3.10	0.91	8.25	92.4
	Total	1.00	*0.64*	*0.38*	*5.91*	*83.8*
Intensive feeding after pasture	Corn silage	0.58	0.50	0.24	6.13	58.9
	Pulses-grain haylage	0.16	0.70	0.47	5.02	79.0
	Extracted soya cake	0.07	12.00	0.88	8.38	352.8
	Winter barley	0.18	3.10	0.88	8.30	77.8
	Dicalcium phosphate	0.01	13.00	1.00	0.00	0.0
	Total	1.00	*1.90*	*0.50*	*6.70*	*114.4*

Table 2.6: Example for energy and protein content in feed rations for bulls and castrates in intensive fattening

Feed ration		Price	Dry matter	Net energy	Protein
Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Corn silage	0.56	0.50	0.24	6.13	58.9
Pulses-grain haylage	0.15	0.70	0.47	5.02	79.0
Extracted soya cake	0.07	12.00	0.88	8.38	352.8
Winter barley	0.22	3.10	0.88	8.30	77.8
Dicalcium phosphate	0.01	13.00	1.00	0.00	0.00
Total	1.00	*1.99*	*0.47*	*7.08*	*107.9*

Table 2.7: Example for energy and protein content in feed rations for heifers in intensive fattening

Feed ration		Price	Dry matter	Net energy	Protein
Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Corn silage	0.58	0.50	0.24	6.13	58.9
Lucerne haylage	0.16	0.70	0.85	5.07	112.4
Winter barley	0.18	3.10	0.88	8.30	77.8
Extracted soya cake	0.07	12.00	0.88	8.38	352.8
Dicalcium phosphate	0.01	13.00	1.00	0.00	0.00
Total	1.00	*1.90*	*0.50*	*6.70*	*114.4*

Table 2.8: Example for energy and protein content in feed rations for breeding bulls on test station

Feed ration		Price	Dry matter	Net energy	Protein
Component	Proportion	Kč/kg	kg/kg	MJ/kg DM	g PDI/kg DM
Corn silage	0.56	0.50	0.24	*6.13*	58.9
Pulses-grain haylage	0.14	0.70	0.47	5.02	79.0
Extracted soya cake	0.07	12.00	0.88	8.38	352.8
Winter barley	0.22	3.10	0.88	8.30	77.8
Dicalcium phosphate	0.01	13.00	1.00	0.00	0.0
Total	1.00	*1.99*	*0.47*	*7.08*	*107.9*

2.5 Revenues and cost of the integrated production systems

2.5.1 Revenues

The revenues in all integrated cattle production systems come from the sale of weaned or reared calves, pregnant or not pregnant breeding heifers, selected breeding bulls, slaughtered heifers, bulls, castrates, culled cows, sale of manure and governmental subsidies. The revenues from milk and sale of cross-bred breeding heifers are to be added in the dairy system. Revenues from slaughtered animals are calculated from the live weight at slaughter, dressing percentage and average price received per kg of carcass weight.

2.5.1.1 Calculation of the price per kg carcass weight

The average price per kg of carcass depends on the distribution of carcasses over the commercial carcass grading classes according to fleshiness and fat covering. Assuming n_{FL} classes for fleshiness and n_{FC} classes for fat covering, a $n_{FL} \times n_{FC}$ matrix $\mathbf{P}_i$ is constructed for each category i of animals whose elements P_{ijk} are the frequencies of animals belonging to the jth class of fleshiness and kth class of fat covering. The price for the combination of fleshiness class j and fat covering class k is calculated as the product from a base price and a coefficient for this combination of classes. In the default set of parameters for the program, the SEUROP grading system with 6 classes for fleshiness (originally S, E, U, R, O, P, in the program the figures 1 to 6 are used instead) and 5 classes for fat covering (1 to 5) is used. It makes sense to use as base price the price for the best combination of classes which might be S1 in the SEUROP system. But the base price may be the price for any combination of classes.

The $n_{FL} \times n_{FC}$ matrix of these coefficients for multiplying the base price with is called $\mathbf{K}_i$ with the elements k_{ijk}. The coefficient for the combination of classes

$j' \times k'$with base price ($k_{ij'k'}$) must be naturally set to 1. If the base price is chosen as the maximal price, all remaining elements of the matrix will be not greater than 1. The average price per kg carcass for category i of fattened animals and culled cows (pr_i) is then calculated as

$$pr_i = prbase_i \sum_{j=1}^{n_{FL}} \sum_{k=1}^{n_{FC}} k_{ijk} P_{ijk} \tag{2.14}$$

where $prbase_i$ is the base price (see also [22]).

In the program, animals culled before reaching the demanded slaughter weight can be given a lower price per kg carcass and a lower value for dressing percentage than animals reaching the demanded slaughter weight.

2.5.1.2 Calculation of the milk price

The milk price depends on the paying system used. There is a great variety in paying systems for milk. Usually, the price for milk that is payed farmers by dairies depends on milk quality and on milk composition. The program allows accounting the average milk price for somatic cell count, milk fat and milk protein content. Five different options are taken into account (see Section 4.1.1.14 for details). Choose among these options that one which is adequate for your system. If you will not find an appropriate option describing the situation in your production system, contact the authors of the program. In the following sections, the calculation of milk price for each of the five options is described in some detail.

2.5.1.2.1 Option 1 for *milkprice*: the milk price does neither depend on the somatic cell count nor on the protein and/or the fat content. The milk price is an input parameter. Prepare input file INPUT28.TXT as shown in Example 1 for INPUT28.TXT on page 85. The number of milk quality classes according to somatic cell count ($nSCC$) is automatically set to 1 in the program.

2.5.1.2.2 Option 2 for *milkprice*: The milk price ($prmilk$) depends (only) on somatic cell count. Several milk quality classes for the somatic cell count are assumed. Insert a number >1 for the number of these classes ($nSCC$) in the file INPUT28.TXT. In the same input file, insert $nSCC$ numbers in the vector of basic prices per kg milk in quality class i ($prSCC[i]$) and $nSCC - 1$ numbers in the vector of upper limits for the somatic cell count in the individual milk quality classes. Further input parameters are the mean somatic cell score and the phenotypic standard deviation of the somatic cell score. Assuming a normal distribution for the somatic cell score, the proportions of sold milk in quality class i ($pSCC[i]$) are calculated. Then, the milk price is calculated as follows:

$$prmilk = \sum_{i=0}^{nSCC-1} pSCC[i] \cdot prSCC[i] \tag{2.15}$$

2.5.1.2.3 Option 3 for *milkprice*: The milk price depends (only) on the fat and/or the protein content. Assume that there are $nfat$ and/or $nprot$ threshold values for fat and/or protein content (a special case is a zero number of threshold values). That means there will be $nfat$+1 ($nprot + 1$) classes (intervals) for fat (protein) content. Within each class (interval), a linear regression on fat (protein) content is assumed which is described by three parameters: a constant (b_0), the regression coefficient (b_1) and a reference value (x_r) for fat or protein

content for which the basic milk price is payed:

$$y = b_0 + b_1(x - x_r) \tag{2.16}$$

where y is the value to be added to the basic milk price (*prmilkb*), the first input parameter in file INPUT28.TXT, for the given value of x, x being milk fat or milk protein content. For some more details and for the way how to describe a concrete situation in the input file INPUT28.TXT see Section 4.3.11.

The milk price is calculated as

$$prmilk = prmilkb + \sum_{i=1}^{nfat+1} F_i + \sum_{i=1}^{nprot+1} P_i \tag{2.17}$$

where F_i is the value from the ith class of fat content which is added to the basic milk price and P_i is the appropriate value from the ith class of protein content. For calculating these values, it is assumed that the milk fat and milk protein content are normally distributed with a given mean and standard deviation (input parameters). From this normal distribution, the proportion of the individual classes can be calculated. For the special case that $b_0 \neq 0$ and $b_1 = 0$, F_i or P_i are simply calculated by multiplying the proportion of fat (protein) content values in class i by the constant b_0. If the regression coefficient b_1 is different from zero, the given interval is subdivided into 500 intervals of equal width. For each interval, the proportion of fat (protein) content values being within is calculated and multiplied by the mean x-value of the interval and the regression coefficient b_1. F_i or P_i are then calculated as the sum of these 500 values.

2.5.1.2.4 Option 4 for *milkprice*: The milk price (*prmilk*) depends both on somatic cell count (SCC) and fat and/or protein content. The base prices for quality classes according to SCC are set first and then these prices are corrected for fat and/or protein content. First, a preliminary milk price is calculated according to equation (2.15). The further correction on the fat and/or protein content of the milk is carried out using equation (2.17) where the preliminary milk price calculated before is inserted for the variable *prmilkb*.

2.5.1.2.5 Option 5 for *milkprice*: The milk price (*prmilk*) depends both on somatic cell count (SCC) and fat and/or protein content. The base price for milk (milk carrier or milk with given fat and/or protein content) is determined first. Then this price is corrected for the real fat and/or protein content. At the last step, a further correction of the price for milk quality classes based on SCC is carried out. First, a basic milk price (*prmilkb*, first input parameter in INPUT28.TXT) must be given. Then equation (2.17) is used to correct the price for the fat and/or protein content of the milk. Let us write $prmilkfp$ for the resulting (preliminary) milk price. For each quality class i of milk according to somatic cell count, a multiplicative ($facSCC[i]$) and an additive ($prSCC[i]$) price correction factor are read from INPUT28.TXT. Then the final milk price is:

$$prmilk = \sum_{i=0}^{nSCC-1} pSCC[i]\,(prmilkfp \cdot facSCC[i] + prSCC[i]) \tag{2.18}$$

where $pSCC[i]$ has the same meaning as in (2.15). Several of the multiplicative ($facSCC[i]$) and additive ($prSCC[i]$) price correction factors may take a value of zero. No change of the milk price means that the multiplicative correction factor is 1 and the additive factor zero. If you want add or subtract a constant to or from

the milk price in the given milk quality class, the multiplicative correction factor is 1 and the additive factor is a positive or a negative constant, respectively. If you want the final milk price to be 30% of the preliminary price, set the multiplicative constant to 0.3 and the additive constant to 0. If you desire to set the milk price to a constant independent off the preliminary price, set the multiplicative factor to zero and the additive factor to the constant. See also examples for input file INPUT28.TXT in Section 4.3.11 on page 84.

2.5.2 Costs

The costs are related to feeding of animals, housing, veterinary treatment, dystocia, other costs and fixed costs. The *cost for feeding* are calculated on the base of daily net energy and protein requirement of animals and from the price for feed with given dry matter, net energy and protein content (see Section 2.4). Daily net energy and protein requirement cover requirements for maintenance, growth, lactation and pregnancy. Feeding for suckler cows with calves, breeding heifers, bulls and for extensively fattened young animals is assumed to be different between the summer and winter periods. Basically, it is expected that energy and protein requirements are supplied entirely by pasture during summer, but the summer and winter feed rations as well as the feed rations in intensive fattening and the appropriate losses of feed can be set by the user of the program.

An example of feeding rations for pure-bred Charolais is given in Tables 2.1-2.8. The values printed in italics are the input parameters that were used as default values for the program. The feeding costs include also costs for water and minerals. The costs for feed from the pasture should be estimated only on the base of direct costs per ha of pasture per year (fertilisation, labour, machinery, repairing costs for folding).

When calculating feed costs, two different feeding periods according to the season (summer and winter or dry and wet periods) can be distinguished in beef cattle (program EWBC). In the dairy system (program EWDC), two feeding periods for rearing calves are distinguished. The feeding ration for the first feeding period is usually based on milk mainly.

If phase feeding with different feeding rations will be applied for an animal category (e.g. for bulls in fattening) the structure of the average feeding ration should be calculated on the base of the total amount of the different feed components in the whole period for which the feeding cost should be calculated.

Depreciation costs for buildings are included in fixed costs per cow and depend on the size of the cow herd. The *costs for housing* are the difference between the costs for straw and the revenues for manure and are expressed per animal and day. In the cow herds on pasture and in extensive fattening, they are calculated only for the winter period, whereas for intensive fattening, they are taken into account throughout. The amount of straw needed depends on the housing technology. As the price per kg manure is usually higher than for straw, these costs have generally a negative sign.

The *costs for veterinary treatment* include veterinary fees and drugs and are expressed per animal of a given category. Therefore, they are not expected to change with a small alteration in the length of the fattening or rearing period. Dystocia costs are calculated per calving in the herd. They depend on the proportion of calvings in each calving score and on veterinary and labour costs connected with these scores.

Other costs are expressed per animal of a given category and include costs for removing and damming dead animals (for categories that died) or breeding costs for heifers and cows. Breeding costs are costs for insemination and natural mating. Costs for natural mating per female are calculated on the base of the price for

breeding bulls, costs for keeping this bulls in the herd and from the number of females per bull and per reproductive cycle. The breeding costs are lowered by the revenues from culled breeding bulls.

Fixed costs are all remaining costs in the system: costs for labour, energy, insurance, interest of investment etc. They depend mainly on the farm size and housing technology and are expressed per animal of the given category and per day. They are treated as variable costs in respect to the length of the fattening or rearing period. For example, they change with changing growth rates of animals in fattening or in the rearing period of heifers. That means that an alternative use of saved production factors (e.g. fattening places) is expected considering the production in long-range terms.

Culling animals of a given category for health problems and death of animals is expected to be equally distributed over the period for which the costs are calculated. Therefore, for simplicity, it is assumed that these animals are culled or died on average in the middle of the period and all costs of these categories of animals refer to this date.

2.5.3 Economic efficiency of the production systems (profit)

The economic efficiency of all production systems is expressed as profit per cow entering a reproductive cycle and per year. Profit is calculated as the difference between the total revenues and total costs obtained per cow and her progeny born per year.

The possibility to take into account the time delay between the birth of progeny of a cow and the occurrence of revenues and costs from these progeny is given in the model. This possibility is used if a value different of zero is put for the input parameter *discount rate* in the input file INPUT03.TXT of program EWBC (Systems 1 to 3, see Section 4.2.3) or the input file INPUT11.TXT of program EWDC (System 4, see Section 4.3.2). In this case, all revenues and costs occurring in the herd within a year and in the whole life of progeny born in the herd during the year are discounted to the birth of the progeny by the given discount rate. The discount rate should be a combination of the average yearly interest and inflation.

In mathematical terms, the total profit (TP) is calculated as

$$TP = \mathbf{rev}'\mathbf{NDE}^{[\mathbf{rev}]} - \mathbf{cost}'\mathbf{NDE}^{[\mathbf{cost}]} + Subsidies \tag{2.19}$$

with

$$\mathbf{NDE}^{[\mathbf{rev}]} = \mathbf{l} \odot \mathbf{q}^{[\mathbf{rev}]}, \qquad \mathbf{NDE}^{[\mathbf{cost}]} = \mathbf{l} \odot \mathbf{q}^{[\mathbf{cost}]} \tag{2.20}$$

the elements of vectors $\mathbf{q}^{[\mathbf{rev}]}$ and $\mathbf{q}^{[\mathbf{cost}]}$ being

$$q_i^{[rev]} = (1+u)^{-t_i^{[rev]}}, \quad q_i^{[cost]} = (1+u)^{-t_i^{[cost]}} \tag{2.21}$$

where **rev** and **cost** are the column vectors of revenues and costs, respectively, per animal, the elements of which are rev_i and $cost_i$, i being the category of animals ($i = 1, ..., CC$ in program EWBC and $i = 1, ..., CT$ for program EWDC), the apostrophe stands for the transpose (i.e. $\mathbf{rev}'$ and $\mathbf{cost}'$ are the appropriate row vectors), $\mathbf{NDE}^{[\mathbf{rev}]}$ and $\mathbf{NDE}^{[\mathbf{cost}]}$ are the column vectors of the number of discounted expressions connected with revenues and costs, respectively, the elements of which are $NDE_i^{[rev]}$ and $NDE_i^{[cost]}$, $\mathbf{l}$ is a column vector which elements l_i are the numbers of animals in category i per cow and year in the stationary state of the production system, $\mathbf{q}^{[\mathbf{rev}]}$ and $\mathbf{q}^{[\mathbf{cost}]}$ are the column vectors of discounting coefficients for revenues and costs, respectively, with elements $q_i^{[rev]}$ and $q_i^{[cost]}$, u is the annual discount rate, $t_i^{[rev]}$ and $t_i^{[cost]}$ are the intervals between calving and the

time when revenues and costs occur in category i, and $\odot$ is the Hadamard product (element-wise product) of the two vectors. The *Subsidies* are per cow and year.

Using this approach, all revenues and costs occurring in the cow herd during the year and in the life of progeny born in this herd per year are discounted to the date of calving (birth of progeny). The life of progeny covers the time from birth to slaughter, to death, to selling or to 1st calving of heifers. The time delay between birth and the occurrence of revenues and costs can be neglected when setting the discount rate zero. In this case the NDEs reduce to the number of animals per cow and year in the given categories.

The profitability including subsidies ($Profitabd$) is calculated as

$$Profitabd = 100 \times TP/TC \tag{2.22}$$

where TP is the total profit and TC is the total cost. In addition, the profitability without subsidies ($Profitab$) is calculated as

$$Profitab = 100(TP - Subsidies)/TC \tag{2.23}$$

The subsidies are per cow and year.

2.6 Traits the economic values are calculated for

2.6.1 Growth traits

All growth traits are mostly measured in both sexes. When calculating the economic weights, the appropriate traits for females are considered first. Generally, changes of the same trait in male animals are assumed to be proportional to the changes in the female animals. The same proportions between female and male traits as given by the input data are used in all calculations. The economic values are then expressed per unit of the trait on females and per cow and year. The economic values of all growth traits depend on feed cost because no economic values are calculated both for feed intake and for feed conversion.

Normally, three weighings are assumed. If only two weighings are available, the following trick can help to make the program work. Set the input parameters in INPUT06.TXT (see Section 4.2.6) as follows:

- Insert your first known age and weight of male and female calves (e.g. age and weight at weaning) as values for the first weighing.
- Insert the values for your second weighing as input parameters for the third weighing.
- Construct a fictive second weighing very close to the first weighing. Use as input parameters age at first weighing + 1 and weight as first weighing + gain in weight for one day calculated from the average daily gain from birth to first weighing.
- Ignore the economic weight for daily gain from 1st to 2nd weighing and for weight of calves at 2nd weighing in the results.
- The economic weight for daily gain from your 1st to 2nd weighing is printed as the economic weight for daily gain from 2nd to 3rd weighing. The economic weight for weight of calves at your 2nd weighing is printed as the economic weight for weight of calves at 3rd weighing.

2.6.1.1 Mature weight

In cows, mature weight is defined as the average weight after 3rd calving. An increase in mature weight of cows is assumed to evoke a proportional increase in mature weight of bulls of the same breed. A correlated increase in the optimal slaughter weight of fattened animals is assumed as well. Furthermore, in production system 4 (program EWDC) a correlated increase of the weight of heifers at first mating is taken into account.

2.6.1.2 Birth weight of calf

The effect of birth weight on calving performance or calf mortality is not included when calculating the economic weight of birth weight as calving performance and calf mortality are evaluated separately.

2.6.1.3 Average daily gain of calves from birth to 1st weighing or weight of calves at 1st weighing as alternative trait (only in program EWBC)

The average daily gain in the following periods is held constant when calculating the economic weight of this trait. Alternatively, the weight of calves at the 1st control weighing can be defined as trait the economic weight is calculated for. The weights at the following controls are then held constant during the calculation.

2.6.1.4 Average daily gain of calves from 1st to 2nd weighing or weight of calves at 2nd weighing as alternative trait (only in program EWBC)

The average daily gain or the weights, respectively, in the previous and the following periods are held constant when calculating the economic weight of this daily gain.

2.6.1.5 Average daily gain of calves from 2nd to 3rd weighing or weight of calves at 3rd weighing as an alternative trait (only in program EWBC)

The average daily gain or the weights, respectively, in the previous and the following periods are held constant when calculating the economic weight of this daily gain.

2.6.1.6 Average daily gain of calves in the rearing period (only in program EWDC)

This trait is evaluated only in Production System 4. The economic value of this traits takes into account correlated changes in daily gain of heifers until calving and of breeding bulls till selling (if bulls are reared on farm). Also the effect of average daily gain on the age of heifers at first mating is considered when calculating the economic value as heifers are mated at fixed weight.

2.6.1.7 Average daily gain in the fattening period to constant slaughter weight.

The average daily gain in the previous periods is held constant when calculating the economic weight of this daily gain.

2.6.2 Carcass traits

2.6.2.1 Dressing percentage

The calculation of dressing percentage is based on similar principles as the calculation of growth traits (starting with changes in females and taking into account proportional changes in males). In systems producing their own replacement (Production Systems 1, 2 and 4) a proportional increase in dressing percentage of cows is also assumed.

2.6.2.2 Average class of fleshiness and fat covering of carcass

The traits are defined as average classes for fleshiness and fat covering in fattened animals and culled cows and heifers. The numbers of classes for fleshiness and fat covering are input parameters in the input file INPUT08.TXT (see Section 4.2.7).

2.6.3 Functional traits

2.6.3.1 Average score for calving performance

Calving performance is measured by a score between one (calving without assistance) and a value up to six. For defining dystocia, the user of the program has to give the lowest number of the score of calving performance which is considered to be dystocia (in input file INPUT11.TXT, see on page 74). Scores higher or equal to that value (mostly 3) are called dystocia, scores less than this value are called calving ease. The trait is expressed as average score for calving performance.

When calculating the economic value of calving score, primarily the average calving score for female calves is changed, but the proportional change in the calving score for male calves is taken into consideration too. A modification of the average score for calving performance has an impact on the culling rate of cows, the proportion of calves stillborn and died until 48 hours after birth and on the conception rate.

2.6.3.2 Losses of calves at calving

Losses of calves at calving included cow aborts, calves born dead and calves died till 48 hours after calving. Calf losses at calving are defined as the number of dead calves expressed as proportion of the number of calvings in one reproductive cycle of the cow herd for the given dystocia rate.

2.6.3.3 Losses of calves from 48 hours till weaning or till the end of the rearing period

This trait is defined as number of dead calves expressed as proportion of the number of calves alive after 48 hours after calving in one reproductive cycle of the cow herd.

2.6.3.4 Conception rate of heifers

Conception rate is defined as the number of heifers conceived in their 1st oestrus in the given mating period expressed as proportion of the heifers mated in this mating period. A proportional increase in the conception rates of heifers in their next oestrus cycles in the same mating period is assumed.

2.6.3.5 Conception rate of cows

Conception rate is defined as the number of cows conceived in their 1st oestrus in the given mating period expressed as proportion of the cows mated after easy calving in this mating period. A proportional increase in conception rates of cows in their next oestrus cycles in the same mating period is assumed.

2.6.3.6 Cow losses or average lifetime of cows (cow longevity) as an alternative trait

Cow losses are defined as cows not surviving to the next reproductive cycle expressed as proportion of the cows entering the given reproductive cycle excluding the cows culled due to problems caused by dystocia, due to low milk production or due to failure to conceive. Cow losses in each reproductive cycle are calculated as the sum of cows died and cows culled for health problems other than dystocia.

The average lifetime of a cow (in years) is an alternative definition of this trait. It is calculated as the average productive lifetime of all heifers that entered the herd.

2.6.4 Milk production traits

These traits are calculated only in production system 4 (program EWDC).

2.6.4.1 Milk yield

The trait is defined as the average 305-day milk yield per cow in the herd. The economic value of this trait is calculated by multiplying the whole lactation curve with a factor (1.005: for increasing the trait, 0.995: for decreasing the trait). This procedure preserves the shape of the lactation curve.

2.6.4.2 Fat content or fat yield as an alternative trait

The trait is defined as fat yield per kg milk at constant milk yield and is expressed in per cent. An alternative trait expression is fat yield in kg in a 305d-lactation, but also in this case the milk yield is held constant that means that an increase in fat yield is given through increasing the fat content.

2.6.4.3 Protein content or protein yield as an alternative trait

The definition of these traits is in the same sense as for fat content and fat yield.

2.6.4.4 Somatic cell score

Somatic cell count (SCC) is defined as the average number of somatic cells per ml milk. The somatic cell score (SCS) is calculated from the somatic cell count as follows [2, 10]:

$$SCS = \log_2 \left(\frac{SCC}{100000} \right) + 3 \tag{2.24}$$

In the opposite way, the somatic cell count can be calculated from the somatic cell score:

$$SCC = 100000 \times 2^{SCS-3} \tag{2.25}$$

2.6.5 Mastitis incidence

Mastitis incidence is defined as the average clinical mastitis incidence (number of clinical mastitis cases per cow-year at risk in the herd).

2.7 Calculation of economic values

2.7.1 Traits with continuous variation - standard situation

The *marginal economic value* ev is defined as the partial derivative of the profit with respect to the trait considered. Let TV_h be the value of the trait considered which was derived as $TV_h = 1.005TV_{av}$ that means by increasing the average value of the trait TV_{av} by 0.5%. Similarly, TV_l is calculated by decreasing the average trait value by the same amount: $TV_l = 0.995TV_{av}$. Furthermore, let TP_h and TP_l be the total profit belonging to the first or the second of these values, respectively. The partial derivative is then approximated by the following difference quotient:

$$ev = \frac{TP_h - TP_l}{TV_h - TV_l} \ . \tag{2.26}$$

The marginal economic value is expressed in monetary units (MU) per unit of the trait.

2.7.2 Traits with continuous variation - atypical situation with zero average values

Mainly in traits which are measured as a fraction which is in the interval between zero and one, as in traits 2 (losses of calves at calving), 3 (losses of calves from 48 hours till weaning or till the end of the rearing period) and 11 (cow losses), it might happen in extreme situations that the average value of this trait is zero. (For numbering of traits in the program see Appendix A.2 on page 98.) This case is handled in the following way in the program:

TV_h is set 0.01 and TV_l is set 0.00. These values are used to calculate the appropriate values of the total profit (TP_h and TP_l) and the economic value is calculated by equation (2.26) given in the preceding Section 2.7.1.

2.7.3 Categorical traits - standard situation

The economic values for categorical traits (calving performance, fleshiness and fat covering) were calculated according to [19]. The calculation was based on a threshold model. The underlying normal distribution was shifted to the left and to the right, each time by 0.05 standard deviations. The resulting changes in the distribution were recalculated to changes in the average class. For the numerical expression of the average class, the numbers 1 to N were assigned to the individual classes. Let p_i be the frequency of animals in class i. Then the average class AC was calculated simply as

$$AC = \sum_{i=1}^{N} ip_i \ . \tag{2.27}$$

Let AC_h be the average class for shifting the distribution to higher values of the trait and let AC_l be the average class for shifting the distribution to lower values of the trait. Furthermore, let TP_h and TP_l be the total profit belonging to the first or the second of these values, respectively. Then the marginal economic value ev is calculated as change of total profit related to a change in the average class by 0.01:

$$ev = 0.01\frac{TP_h - TP_l}{AC_h - AC_l} \ . \tag{2.28}$$

2.7.4 Categorical traits - atypical situation: only one class

In extreme situations it can happen that all data are in one class only. In this case it will not be possible to estimate the thresholds of the underlying normal distribution. We suppose to develop an automatic procedure in the program for this case in future. At the moment, we recommend the following procedure to get out of this situation. Change your input values in the way that you allocate a very small amount of data to the neighbouring classes. For example, there are 100% data in class 2. Then the situation will not considerably change when assigning 1% to each of classes 1 and 3 and leave 98% in class 2. The mean class will be the same as before and the calculation of the economic values will work. But you should ponder if it will make sense to calculate an economic weight in such a situation without measurable variability.

2.7.5 Calculation of economic values in the situation with milk quota

For calculating economic values under the situation with quota, the total profit will be rewritten as

$$TP = n_{cow} TP_0 \tag{2.29}$$

where n_{cow} is the number of cows and TP_0 the total profit per cow. Generally, the economic value is defined as partial derivation of the total profit with respect of the given trait which can be numerically approximated by the difference quotient (see equation (2.26)). If there is a milk quota, the total amount of milk is assumed to stay constant. An increase in the amount of milk is then reflected by a decrease in the number of cows. We can write

$$ev = \left.\frac{\partial TP}{\partial TV}\right|_{TV=TV_{av}} = \frac{\partial n_{cow}}{\partial TV} TP_{0[av]} + \frac{\partial TP_0}{\partial TV} n_{cow[av]} \tag{2.30}$$

where TV is the value of the given trait, TV_{av} is the average of the given trait in the population, $TP_{0[av]}$ is the value of the total profit per cow when all traits take their average values and $n_{cow[av]}$ is the number of cows when all traits take their average values. As the total profit is calculated per cow, $n_{cow[av]} = 1$.

Numerically the marginal economic value is then calculated as

$$ev = \frac{n_{cow[h]} - n_{cow[l]}}{TV_h - TV_l} TP_{0[av]} + \frac{TP_h - TP_l}{TV_h - TV_l} \tag{2.31}$$

where TV_h, TV_l, TP_h and TP_l have the same meaning as in (2.26) and $n_{cow[h]}$ and $n_{cow[l]}$ are the number of cows for the high or the low value of the trait (TV_h or TV_l, respectively). The first term in equation(2.31) is zero for all traits the change of the value of which is of no influence on the total amount of milk and therefore on the number of cows.

A fat quota has only impact on the calculation of the economic weight for milk fat content and milk fat yield. A change in the fat content will cause a change in the total amount of fat which must be counterbalanced by an adequate change in the number of cows.

2.7.6 Remark to the calculation of economic weights in Production System 4

In System 4, traits expressed in pure-bred (dairy) and cross-bred (dairy x beef) animals are treated separately. That means, the economic values are calculated in separate runs for pure-bred and cross-bred animals and expressed per pure-bred or

per cross-bred calving. The reason for this approach is the fact shown in many studies that the economic values depend on the level of the trait (e.g. Wilton et al. 2002 [14]). As there are mostly considerable differences between the performance of pure-bred and cross-bred animals this procedure seems to be justified.

2.7.7 Final remarks

Read carefully the output of the program when considering the economic values. The economic values for daily gain will be given per gramme, the trait itself has the unit kg. Therefore, do not read only the numbers, but also the units belonging to them. Furthermore, an increase in the average value of a trait does not always mean an improvement of the trait. Take this fact into account when interpreting the sign of the economic values.

2.8 Gene flow, number of discounted expressions for maternal and direct effects of traits and economic weight for direct and maternal effects of traits

In general, all traits can be divided in two main groups: (i) direct traits realized once in the life of an animal and (ii) maternal traits realized repeatedly during the life of dams [18]. Some traits have both direct and maternal components (calving performance, growth). Although the economic values for both components of a trait could be the same (e.g. for calving performance), the number of expressions for these components transmitted by bulls are different and depend also on the production system (e.g. the number of expressions for maternal calving performance of beef bulls is zero in Production System 3). To take this fact into account when defining the breeding goal for beef bulls for different production systems, the calculation of the number of discounted expressions for the two groups of traits and the selection groups of interest (e.g. beef bulls) has been included in the program. The gene flow method developed by Hill [5] and Elsen and Mocquot [3] is applied for this calculation. The number of discounted expressions for trait group j and selection group k in production system p is calculated as follows (see also Nitter et al. [7]):

$$NDE_{jkp} = \mathbf{h'_j} \sum_{t=1}^{T} \mathbf{m_k^{[t]}} (1+u)^{-t} \tag{2.32}$$

with

$$\mathbf{m_k^{[t]}} = \mathbf{P_p m_k^{[t-1]}} = \mathbf{P_p^2 m_k^{[t-2]}} = \cdots = \mathbf{P_p^t m_k^{[0]}} \tag{2.33}$$

where T is the investment period (in years) during which the gene expressions are summarised, $\mathbf{m_k^{[t]}}$ is a vector whose elements define the proportion of genes in each sex-age class at time t that come from the original group k of selected animals at time 0, $\mathbf{P_p}$ is the matrix of transition probabilities for production system p which relates the proportion of genes in each sex-age class represented in $\mathbf{m_k^{[t-1]}}$ to the proportion of genes of the sex-age classes in $\mathbf{m_k^{[t]}}$, $\mathbf{h_j}$ is a vector which describes the realization of trait group j ($\mathbf{h'_j}$ is the transpose of $\mathbf{h_j}$) and u is the discount rate per year.

Notice that within both groups of traits the NDE_{jkp} are equal for all traits because the marginal economic values of all traits are expressed per cow and year and

discounted to the time of calving (to birth of progeny). The number of animals in different categories (born per cow and year) expressing a certain trait and the time delay between the expression of this trait and the animal's birth are already taken into account in the calculation of the marginal economic values. Therefore, the NDE in Section 2.5 represent differences in expressions of traits within one generation of progeny. The NDE_{jkp} calculated in this section, on the other hand, show the transmission of genetic superiority of selected animals for direct or maternal traits to subsequent generations during the investment period.

2.8.1 Matrix $\mathbf{P_p}$ for Systems 1 to 3

Matrix $\mathbf{P_p}$ differs between production systems. In Production System 1, it looks as follows:

$$\mathbf{P_p} = \mathbf{P}_1 = \begin{array}{c} \\ \text{Sires} \\ \\ \\ \\ \\ \\ \text{Dams} \\ \\ \\ \\ \\ \\ \text{Slaughter animals} \end{array} \begin{array}{c} \begin{array}{cccccc|cccccc|c} \text{Sires} & & & & & & \text{Dams} & & & & & & \text{Slaughter animals} \end{array} \\ \left[\begin{array}{cccccc|cccccc|c} x & x & x & \cdots & x & x & x & x & x & \cdots & x & x & 0 \\ 1 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 1 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 & 0 & 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 1 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ \hline x & x & x & \cdots & x & x & x & x & x & \cdots & x & x & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 1 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 1 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 1 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 & 0 & 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 1 & 0 & 0 \\ \hline x & x & x & \cdots & x & x & x & x & x & \cdots & x & x & 0 \end{array}\right] \end{array}$$

The matrix has a block structure containing 3x3 blocks in Production Systems 1 to 3. The blocks are made up by age classes of sires, age classes of dams and one class of slaughter animals. The elements $P_{ii'}$ of $\mathbf{P_p}$ are the proportions of genes in the sex-age class i at time t which come from the sex-age class i' at time $t-1$. The sum of all elements $P_{ii'}$ within each row is 1 and the sum of all elements $P_{ii'}$ within each row belonging to the same sex is 0.5. The symbol "x" stands in the matrix for elements which can be different from zero (The values of "x" are in the range from 0 to 0.5).

In Production System 2, matrix $\mathbf{P_p}$ has the following structure:

$$\mathbf{P_p} = \mathbf{P}_2 = \begin{array}{c} \\ \text{Sires} \\ \\ \\ \\ \\ \\ \\ \text{Dams} \\ \\ \\ \\ \\ \\ \\ \text{Slaughter animals} \end{array} \begin{array}{c} \begin{array}{cccccc} \text{Sires} & & & & & \end{array} \quad \begin{array}{cccccc} & & & \text{Dams} & & \end{array} \quad \begin{array}{c} \text{Slaughter} \\ \text{animals} \end{array} \\ \left[\begin{array}{cccccc|cccccc|c} 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 & 0 & 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ \hline \mathrm{x} & \mathrm{x} & \mathrm{x} & \cdots & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \cdots & \mathrm{x} & \mathrm{x} & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 1 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 1 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 1 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 & 0 & 0 & 0 & \ddots & 0 & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 1 & 0 & 0 \\ \hline \mathrm{x} & \mathrm{x} & \mathrm{x} & \cdots & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \mathrm{x} & \cdots & \mathrm{x} & \mathrm{x} & 0 \end{array}\right] \end{array}$$

and in Production System 3 non-zero elements are conserved only in the last row of the matrix.

2.8.2 Matrix $\mathbf{P_p}$ for System 4

In Production System 4 with terminal crossing and with connection to System 3 (if cross-bred beef x dairy heifers from Production System 4 are transferred to cow-calf pasture System 3), matrix $\mathbf{P_p}$ has 7 x 7 block structure:

$$\mathbf{P_p} = \mathbf{P_4} = \begin{bmatrix} \mathbf{P_{11}} & \cdots & \mathbf{P_{17}} \\ \vdots & \ddots & \vdots \\ \mathbf{P_{71}} & \cdots & \mathbf{P_{77}} \end{bmatrix} \tag{2.34}$$

The blocks represent age classes of beef sires, dairy dams, dairy sires (in System 4), cross-bred dams (in System 3), dairy slaughter progeny, cross-bred slaughter progeny of dairy dams (in System 4) and cross-bred slaughter progeny of cross-bred dams (in System 3). In the latter three blocks, there is always only one class. All submatrices of $\mathbf{P_p}$ have one of the following structures:

$$\mathbf{S_1} = \begin{bmatrix} x & x & x & \cdots & x & x \\ 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix}, \quad \mathbf{S_2} = \begin{bmatrix} x & x & x & \cdots & x & x \\ 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 0 & 0 \end{bmatrix},$$

$$\mathbf{S_3} = \begin{bmatrix} x & x & x & \cdots & x & x \end{bmatrix}, \quad \mathbf{S_4} = \begin{bmatrix} 0 & 0 & 0 & \cdots & 0 & 0 \\ 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 \\ 0 & 0 & 1 & \cdots & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 \\ 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix}.$$

The sub-matrices $\mathbf{P_{22}}$, $\mathbf{P_{33}}$ are of structure $\mathbf{S_1}$, the sub-matrices $\mathbf{P_{23}}$, $\mathbf{P_{32}}$, $\mathbf{P_{41}}$ and $\mathbf{P_{42}}$ are of structure $\mathbf{S_2}$, the sub-matrices $\mathbf{P_{11}}$ and $\mathbf{P_{44}}$ are of structure $\mathbf{S_4}$ and the blocks $\mathbf{P_{52}}$, $\mathbf{P_{53}}$, $\mathbf{P_{61}}$, $\mathbf{P_{62}}$ and $\mathbf{P_{74}}$ are of structure $\mathbf{S_3}$. All other blocks consist of only elements being zero. The elements of $\mathbf{P_{74}}$ sum up to 0.5 and not to one or zero as in all other rows of matrix $\mathbf{P_p}$. If no connection exists between Systems 4 and 3 (all cross-bred progeny are fattened in System 4) all elements of the sub-matrices $\mathbf{P_{41}}$, $\mathbf{P_{42}}$, $\mathbf{P_{44}}$ and $\mathbf{P_{74}}$ are zero.

The potential non-zero elements in matrices $\mathbf{P_p}$ designated with the symbol "x" depend on the breeding program and are input parameters. There is an exception in the path dams to breed dams. The non-zero elements in this block are a result of the herd structure in the stationary state and are calculated by the program on the basis of the input parameters determining the herd structure.

2.8.3 Vectors $\mathbf{m_k}$, $\mathbf{h_d}$ and $\mathbf{h_m}$ for Production Systems 1 to 3 (Program EWBC)

Assume that $k = 2$ that means the selection group of interest are bulls in the second age class. Then the transpose of vector $\mathbf{m_k^{[0]}}$ is:

$$\mathbf{m_2^{[0]\prime}} = \left[\begin{array}{cccccc|cccccc|c} 0 & 1 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{array}\right] \tag{2.35}$$

The realization vectors for direct traits ($\mathbf{h'_d}$) and for maternal traits ($\mathbf{h'_m}$) have the same dimension as $\mathbf{m_k^{[0]}}$ and are of the following form:

$$\mathbf{h'_d} = \left[\begin{array}{cccccc|cccccc|c} 0 & 0 & 0 & \cdots & 0 & 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 1 \end{array}\right] \tag{2.36}$$

$$\mathbf{h'_m} = \left[\begin{array}{cccccc|cccccc|c} 0 & 0 & 0 & \cdots & 0 & 0 & p_{f1} & p_{f2} & p_{f3} & \cdots & p_{fn-1} & p_{fn} & 0 \end{array}\right] \tag{2.37}$$

where p_{fi} is the proportion of cows calving in age classes 1 to n. The elements of $\mathbf{h'_m}$ sum up to 1.

2.8.4 Vectors $\mathbf{m_k}$, $\mathbf{h_d}$ and $\mathbf{h_m}$ for Production System 4

In Production System 4 with a possible connection to Production System 3, the realization vectors for direct traits $\mathbf{h_d}$ and for maternal traits $\mathbf{h_m}$ are of the following form:

$$\mathbf{h'_d} = \left[\begin{array}{c|c|c|c|c|c|c} \mathbf{0'} & \mathbf{0'} & \mathbf{0'} & \mathbf{0'} & p_{dd} & p_{db} & p_{cr} \end{array}\right] \tag{2.38}$$

$$\mathbf{h'_m} = \left[\begin{array}{c|c|c|c|c|c|c} \mathbf{0'} & \mathbf{p'_{d4}} & \mathbf{0'} & \mathbf{p'_{cr}} & 0 & 0 & 0 \end{array}\right] \tag{2.39}$$

with $\mathbf{0'}$ being a row vector with zeros

$$\mathbf{0'} = \left[\begin{array}{cccc} 0 & 0 & \cdots & 0 \end{array}\right] \tag{2.40}$$

and

$$\mathbf{p'_{d4}} = \left[\begin{array}{cccc} p_{d41} & p_{d42} & \cdots & p_{d4n_4} \end{array}\right] \tag{2.41}$$

$$\mathbf{p'_{cr}} = \left[\begin{array}{cccc} p_{cr1} & p_{cr2} & \cdots & p_{crn_c} \end{array}\right] \tag{2.42}$$

where p_{dd} and p_{db} are the proportions of dairy cows in System 4 mated to dairy and beef bulls, respectively, ($p_{dd}+p_{db}=1$), p_{cr} is the number of cross-bred dams in System 3 per dairy cow in System 4, the element p_{d4i} of the vector $\mathbf{p_{d4}}$ is the proportion of pure-bred calvings in age class i ($i=1,...,n_4$) in System 4 ($\sum_{i=1}^{n_4} p_{d4i}=1$) and the element p_{cri} of the vector $\mathbf{p_{cr}}$ is the proportion of cross-bred cows in System 3 calving in age class i ($i=1,...,n_c$) per dairy cow in System 4 ($\sum_{i=1}^{n_c} p_{cri}=p_{cr}$). If no connection exists between Systems 4 and 3, all p_{cri} and consequently p_{cr} take the value of zero. *Note: Differentiate between the vector* $\mathbf{p_{cr}}$ *printed in bold and the sum of its elements* p_{cr} *printed in italics.*

The vectors of economic values for direct ($\mathbf{ev_{sd}}$) and maternal ($\mathbf{ev_{sm}}$) effects of trait s are as follows:

$$\mathbf{ev'_{sd}} = \left[\ \mathbf{0'}\ \middle|\ \mathbf{0'}\ \middle|\ \mathbf{0'}\ \middle|\ \mathbf{0'}\ \middle|\ ev_{sdd}\ \middle|\ ev_{sdb}\ \middle|\ ev_{s3}\ \right] \tag{2.43}$$

$$\mathbf{ev'_{sm}} = \left[\ \mathbf{0'}\ \middle|\ \mathbf{1'}ev_{sdd}\ \middle|\ \mathbf{0'}\ \middle|\ \mathbf{1'}ev_{s3}\ \middle|\ 0\ \middle|\ 0\ \middle|\ 0\ \right] \tag{2.44}$$

with $\mathbf{0'}$ and $\mathbf{1'}$ being a row vector with zeros and ones, respectively:

$$\mathbf{0'} = \left[\ 0\quad 0\quad \cdots\quad 0\ \right], \qquad \mathbf{1'} = \left[\ 1\quad 1\quad \cdots\quad 1\ \right] \tag{2.45}$$

where ev_{sdd} is the economic value for trait s expressed in pure-bred dairy progeny (per one pure-bred dairy calving), ev_{sdb} is the economic value for the same trait expressed in cross-bred progeny (per one cross-bred calving) and ev_{s3} is the economic value for this trait expressed in cross-bred progeny in System 3 (per cross-bred cow in System 3).

2.8.5 Calculation of economic weights

The economic weight $ew_{s(j)kp}$ for trait s within trait group j (two groups: direct and maternal traits) and selection group k in production system p (where $p=1,2$ or 3) is calculated as

$$ew_{s(j)kp} = ev_s NDE_{jkp} \tag{2.46}$$

where ev_s is the appropriate economic value calculated as described in Section 2.7 and NDE_{jkp} is the number of discounted expressions for the given group of traits j and the given selection group k in production system p from equation (2.32).

In System 4 where cross-bred replacement females for System 3 can be supplied, a somewhat different approach is used for the calculation of the economic weights, because the economic value for a given trait will be different when expressed in cross-bred progeny of System 4 or of System 3. Therefore, the realization vectors $\mathbf{h_j}$ have to be multiplied by the vectors of economic values for traits expressed in the different progeny group. In this case, the economic weights in System 4 are calculated as

$$ew_{s(j)k4} = \mathbf{h'_j} \odot \mathbf{ev'_{sj}} \sum_{t=1}^{T} \mathbf{m_k}[\mathbf{t}](1+u)^{-t} \tag{2.47}$$

where ev_{sj} is the joint vector of economic values for trait s within trait group j in Systems 3 and 4. Its form is given above in Section 2.8.4. The symbol $\odot$ stands for the element-wise product of vectors.

The economic weight $ew_{s(j)k}$ for the general breeding goal of the evaluated breed and its selection group k for trait s across all production systems can then be estimated as

$$ew_{s(j)k} = \sum_{p} ew_{s(j)kp} nc_p \tag{2.48}$$

where nc_p is the proportion of cows in production system p with $\sum_p nc_p = 1$. This calculation is not a part of the program yet.

Chapter 3

Installing and running the program

3.1 List of files in the installation package

PARA.TXT, PARAD.TXT Parameter files for the program EWBC and EWDC, respectively (see Section 4.1) .

INPUTxx.TXT with xx = 01, 02, 03, 04, 05, 06, 07, 08, 09, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 or 30 Data input files. Not all files are required for each run. A survey which data input files are needed for a given combination of parameters in the parameter file is presented in Table 4.1. A detailed description of the data input files for program EWBC is given in Section 4.2. The input files for program EWDC are described in Section 4.3.

FROM1_3.TXT Input file for EWDC which transfers preliminary results from EWBC calculated for System 3.

TEXT_OUT.TXT, TEXTD_OUT.TXT These files contain text for writing the results for the program EWBC or EWDC, respectively. For details see Section 4.4.

ewbc.exe, ewdc.exe Executable program files for program EWBC and EWDC, respectively.

license (in subdirectory DOC) This file contains the license conditions. Read them carefully and do not use the program package ECOWEIGHT if you do not agree with the license conditions.

ecoweight.pdf (in subdirectory DOC) Manual of the program package. You can read and print it with the AcrobatReader or any other program which can handle pdf-files.

ewbc.c, ewdc.c (in subdirectory SRC) Source codes of the programs EWBC and EWDC, respectively.

3.2 Installation

3.2.1 Under LINUX

The program package comes to you as a compressed tar-file with the name ew{# of version}.tgz, for example ew1_0_21.tgz is version 1.0.21 of the program. Copy this file to a directory and enter the command

tar xvf ew{# of version}.tgz

for uncompressing and unarchiving the file. All files necessary for running the programs EWBC and EWDC will be installed in the same directory. The subdirectory DOC will contain the file with the license conditions and the manual of the program as pdf-file. The subdirectory SRC will contain the source code of the programs EWBC and EWDC.

For compiling the source code using the compiler gcc you must use the option -lm, because otherwise the mathematical functions would not work. For example, for compiling the source file ewbc.c to receive the executable file ewbc.exe, type:

gcc -lm -o ewbc.exe ewbc.c

3.2.2 Under Microsoft Windows

The Windows version of the program is distributed as zip file. It contains the compiled programs **ewbc.exe** and **ewdc.exe**. The programs were compiled under Cygwin (http:// www.cygwin.com) and run only in the presence of the file cygwin1.dll which is part of the Windows distribution. If you intend to change the source code and to compile the program you are recommended to install Cygwin which is freely available. When compiling the source code, omit the option -lm:

gcc -o ewbc.exe ewbc.c

Alternatively it should be possible to use commercial C compilers (we did not test commercial compilers).

3.3 Running programs EWBC and EWDC

You are recommended to create one directory for each calculation where you will copy and edit all files you will need. The first thing you have to do is to choice a production system. Have a look to Table 4.1 and decide which input files you need. All these input files must be edited and you have to insert the values of the system you are going to model.

3.3.1 Running program EWBC - Calculations for Production Systems 1 to 3

All data input files necessary for Systems 1 to 3 (see Table 4.1 on page 54), the files PARA.TXT, TEXT_OUT.TXT and the executable program file should be located in the same directory (alternatively, the executable program file can be located in /usr/local/bin under LINUX). Edit the parameter file PARA.TXT and the data input files as described in Chapter 4. Enter under LINUX

./ewbc.exe

or under Windows

ewbc.exe

to start the program.

The program will ask you to type the name of the output file the results will be written to. Press ENTER after typing the name of the file.

After finishing the program, you will find all results in the result file. This file is a text file and can be edited by any text editor or word processor.

3.3.2 Running program EWDC - Calculations for Production System 4

If a connection exists between the Production Systems 4 and 3, some results of System 3 are needed for the calculation of economic weights of traits for beef bulls in System 4. Therefore, in this case, System 3 had to be defined and EWBC had to be run before doing the calculation for System 4. The results from System 3 will be written to file FROM1_3.TXT. If there is no connection with System 3, data from file FROM1_3.TXT will be ignored.

All data input files necessary for Systems 4 (see Table 4.1 on page 54), the files PARAD.TXT, TEXTD_OUT.TXT, FROM1_3.TXT and the executable program file **ewdc.exe** should be located in the same directory (alternatively, the executable program file can be located in /usr/local/bin under LINUX). Edit the parameter file PARAD.TXT and the data input files as described in Chapter 4. Enter under LINUX

./ewdc.exe

or under Windows

ewdc.exe

to start the program.

The program will ask you to type the name of the output file the results will be written to. Press ENTER after typing the name of the file.

After finishing the program, you will find all results in the result file. This file is a text file and can be edited by any text editor or word processor.

3.3.3 Example

Assume you want to calculate Production System 3 for variant 1 of fattening (see Section 4.1.1.3) and for the case that the parameters of the lactation curve are read in. Then you should have in the directory for the calculation the following files (E means that you have to edit these files before starting the program):

- ewbc.exe
- PARA.TXT (E)
- INPUT01.TXT (E)
- INPUT02.TXT (E)
- INPUT03.TXT (E)
- INPUT04.TXT (E)
- INPUT06.TXT (E)
- INPUT08.TXT (E)
- INPUT10.TXT (E)
- INPUT14.TXT (E)
- INPUT16.TXT (E)
- INPUT17.TXT (E)
- INPUT20.TXT (E)
- INPUT26.TXT (E)
- TEXT_OUT.TXT

3.3.4 General remarks

Several checks of input parameters are included in the programs. For example, certain input parameters have to sum to one. A warning will appear if these input parameters are invalid and the program will stop. You will be told which input parameters to correct before restarting the program. In general, it is your responsibility to use input parameters which are realistic and fit together, because it is impossible to predict any possible erroneous combinations of input parameters. Do not forget to have always a critical look on your results before using them for further purposes.

Chapter 4

Input files

Important remark: When editing the input files, keep attention *not to change quotation marks*. All files are read as sequential files and the program recognises the beginning and the end of texts on the basis of quotation marks. Adding or deleting a quotation mark will cause the program to break down or to calculate wrong results.

Monetary unit: In all input files the abbreviation MU is used for monetary unit. All values in the distributed version of the program refer to Czech crowns (1 euro is approximately 30 Czech crowns). You can globally replace the abbreviation MU by the abbreviation of your monetary unit in all data input files (INPUTxx.TXT) and in the input files TEXT_OUT.TXT or TEXTD_OUT.TXT using any text editor; the results file will then contain the monetary unit specified by you.

Language of the program: The program will need just the numbers for calculations. The texts are read in and printed out to the result file as they are. Therefore, you can freely change the text in all input files as long as you do not modify the quotation marks. For example, you can translate all texts in the input files to another language what will cause the appropriate part of the result file to be printed in the same language as the input files (may be there are some exceptions where the English text will be remained). The length of the texts can be changed, but each text must start and finish with quotation marks. A great part of the text for the results file is read from the files TEXT_OUT.TXT or TEXTD_OUT.TXT. You can translate all the text in these two files. But be very careful not to change quotation marks.

4.1 Parameter files

The files PARA.TXT and PARAD.TXT contain basic information for the programs EWBC and EWDC, respectively. One row contains the value of the given parameter followed by a row with its description. Modify the values of the parameters according to the instructions given below. At the very beginning of each file there is space for writing a comment which helps you to identify the results. Replace the text in the example file by any text which must begin and end with quotation marks; quotation marks are not allowed to occur within the text.

4.1.1 Basic options of the production systems and for the calculation of economic weights

The following options are used as parameters in the parameter files PARA.TXT and PARAD.TXT.

4.1.1.1 Production system for cow herds

A cow-calf production system with fattening is mostly assumed. The following variants are considered (see also Figure 1.1):

1 Closed pure-bred beef herd with pasture system producing breeding heifers for its own replacement and eventually for sale, and breeding bulls for replacement in all connected systems or for insemination stations

2 Closed beef herd with pasture system applying cross-breeding that produce breeding heifers for its own replacement and eventually for sale but purchase sperm for artificial insemination and/or the breeding bulls for natural mating (e.g. rotational crossing)

3 Open herd with pasture system that purchase pure-bred or cross-bred replacement heifers and bulls or sperm for terminal crossing

4 Dairy or dual purpose cow herd with milk production used partly for cross-breeding with beef bulls; integrated fattening or selling of all cross-bred and excessive dairy progeny.

In PARA.TXT, the parameter file for program EWBC, values 1 to 3 are allowed. In PARAD.TXT, the parameter file for the program EWDC, this parameter is always fixed to 4.

4.1.1.2 Crossing in the system (only for program EWDC)

Two variants are differentiated:

0 No crossbreeding in the system

1 Crossbreeding in the system

4.1.1.3 Variants for fattening (only for program EWBC - Production Systems 1 to 3)

1 Intensive fattening of bulls, heifers or castrates

2 Intensive fattening of bulls, extensive fattening of heifers and castrates on pasture.

4.1.1.4 Variants for housing technology in fattening

1 Bind technology

2 Free technology

3 Pasture (only in program EWBC, not allowed in program EWDC)

4.1.1.5 Maturity type of progeny

In Production System 4, a differentiation is made between the maturity type of pure-bred and the maturity type of cross-bred progeny.

1 Early (animals of small or middle body size of British or American breeds as Aberdeen Angus, Holstein and crosses between them)

2 Medium (breeds Hereford, Sussex and crosses between them as well as crosses between maturity types 1 and 3)

3 Late (animals of large body size of European breeds as Charolais, Limousin, Simmental and crosses between them)

4.1.1.6 Base conditions of the milk market (quota - Production System 4 only)

1 Free market for milk and milk components (fat and protein)

2 Quota system for milk yield only

3 Quota system for milk yield and fat content

4.1.1.7 Parameters of the lactation curve

Both options work only in program EWBC (for Production Systems 1 to 3), use always 1 in program EWDC (for production System 4).

1 The values are read from input file INPUT20.TXT in the program EWBC or from input file INPUT22.TXT in the program EWDC. This option should be used if the user of the program has sufficient information to estimate the parameters of the lactation curve directly. It is preferable to option 2.

2 The parameters are approximately estimated as described in Section 2.3.1. This option should be used when there is not enough information to estimate the parameters of the lactation curve directly.

4.1.1.8 Utilisation of pure-bred female dairy calves which are not needed for replacement (only in program EWDC - System 4)

The following options are available:

1 Selling of surplus reared female calves outside the systems (export)

2 Fattening of surplus reared female calves

3 Selling of surplus breeding heifers before mating

4 Selling of surplus pregnant breeding heifers

4.1.1.9 Utilisation of cross-bred female dairy x beef calves which are not needed for replacement (only in program EWDC - System 4)

1 Selling of reared cross-bred female calves outside the systems (export)

2 Fattening of reared cross-bred female calves

3 Selling (transferring) of cross-bred heifers to the cow-calf Production System 3

4 Combination of fattening and selling of cross-bred female calves

If choice 4 is made, the proportion of sold female calves has to be given (in input file INPUT23.TXT - viz Section 4.3.7 on page 81)

4.1.1.10 Calculation of feeding costs

1 Feeding costs are calculated on the base of the net energy content (expressed in MJ NE) and protein content (expressed in grammes protein digestible in intestine [protéines digestibles dans l'intestin] - PDI) in the feeding rations.

2 Feeding costs are calculated on the base of net energy content in feed (expressed in MJ NE); protein content in feed in PDI units is not available.

4.1.1.11 Mating type (only in program EWBC - for Production Systems 1 to 3)

Mating type occurs twice in the input file PARA.TXT (for heifers and for cows - see Section 4.1.2). The options which are allowed for are equal for both categories of animals (you can choose different options for heifers and cows, of course):

1 Artificial insemination is used in the first oestrus at least within one mating period.

2 Natural mating is used throughout.

4.1.1.12 Gene flow

Gene flow can be calculated for both sexes. The options are for Systems 1 to 3 (program EWBC):

1 Gene flow is calculated for beef sires

2 Gene flow is calculated for beef dams

In System 4 (program EWDC), there are three options:

1 Gene flow is calculated for dairy sires

2 Gene flow is calculated for dairy dams

3 Gene flow is calculated for beef sires

More information on gene flow is given in Section 2.8 and in the papers cited there.

4.1.1.13 Options for the calculation of economic weights in program EWDC (System 4)

0 Economic weights are calculated only for traits expressed in pure-bred dairy progeny (when no terminal crossing is used)

1 Economic weights are calculated only for traits expressed in cross-bred progeny (when only economic weights for beef cattle are of interest)

2 Economic weight are calculated for traits both expressed in pure-bred and cross-bred progeny (when economic weights for dairy cattle are of interest and terminal crossing in dairy herds is used)

4.1.1.14 Options for the calculation of the milk price in program EWDC (System 4)

1 The milk price does neither depend on the somatic cell count nor on the protein and/or the fat content.

2 The milk price depends only on somatic cell count.

3 The milk price depends only on the protein and/or fat content.

4 The milk price depends on both somatic cell count (SCC) and fat and/or protein content. The base prices for quality classes according to SCC are set first and then these prices are corrected for fat and/or protein content.

5 The milk price depends on both somatic cell count (SCC) and fat and/or protein content. The base price for milk (milk carrier or milk with given fat and/or protein content) is determined first. Then this price is corrected for the real fat and/or protein content. At the last step, a further correction of the price for milk quality classes based on SCC is carried out.

4.1.2 Parameter file PARA.TXT for Production Systems 1 to 3 (program EWBC)

An example of the file is:

```
"Between these two quotation marks you can write any comment which helps you to
identify the results"
1
"Production System
  (1 Closed purebred ...
   2 Closed crossbred ...
   3 Open beef x dairy ...)"
1
"Fattening
   (...)"
2
"Housing technology in fattening
   (...)"
3
"Maturity type of progeny
   (...)"
2
"Way of calculating parameters for lactation curve
   (...)"
1
"Way of calculating feeding cost
   (...)"
1
"Mating type for heifers
   (...)"
1
"Mating type for cows
   (...)"
2
"Sex for which gene flow is calculated
   (...)"
20
```

```
"Number of reproductive cycles (...  )"
```

There are certain dependencies between the parameters in the parameter file and further parameters in the data input files which must be taken into account. The following paragraphs list these dependencies.

4.1.2.1 Consequences of changing the parameter 'Mating type for heifers'

The change of this parameter requires an appropriate alteration of the value of 'Heifers mated in 1st oestrus as proportion of mated heifers' in the input file INPUT13.TXT.

4.1.2.2 Consequences of changing the parameter 'Mating type for cows'

Connect please the change of this parameter with a modification of the following parameters from input file INPUT02.TXT:

- Vector of cows having dystocia that were inseminated in 1st oestrus within reproductive cycles 1 to $LL-1$, respectively, as proportion of all mated cows having dystocia in these cycles (if natural mating is used only, set all elements of the vector 1)
- Vector of cows without dystocia that were inseminated in 1st oestrus within reproductive cycles 1 to $LL-1$ as proportion of all mated cows not having dystocia in these cycles (if natural mating is used only, set all elements of the vector 1)

4.1.2.3 Consequences of changing the parameter 'Number of reproductive cycles'

When changing the number of reproductive cycles and calculating Production System 3 with the intension to use the results in program EWDC, change the parameter 'Number of age classes for cross-bred dams' in input file INPUT27.TXT for program EWDC. This parameter is calculated as Number of reproductive cycles in System 3 + age at calving in years - 1.

4.1.3 Parameter file PARAD.TXT for Production System 4 (program EWDC)

An example of the parameter file for program EWDC is:

```
4
   "Production System
   Keep always value 4"
1
   "Crossbreeding in the system
   (0 No crossbreeding used
   1 Crossbreeding used)"
2
"Housing technology in feedlot
   (...)"
3
"Housing technology in cow herds
   (...)"
3
"Maturity type of pure-bred progeny
   (...)"
2
"Maturity type of cross-bred progeny
```

```
   (...)"
1
"Way of calculating parameters for lactation curve - keep always value 1
   (1 The values are read from the input file INPUT22.TXT)"
2
"Utilisation of pure-bred female calves which are not needed for replacement
   (...)"
3
"Utilisation of cross-bred female calves which are not needed for replacement
   (...)"
1
"Way of calculating feeding cost
   (...)"
2
"Option for calculating economic weights
   (0 Economic weights are calculated only for traits expressed in
      pure-bred dairy progeny (when no terminal crossing is used)
    1 Economic weights are calculated only for traits expressed in
      cross-bred progeny (when only economic weights for beef cattle
      are of interest)
    2 Economic weight are calculated for traits both expressed in
      pure-bred and cross-bred progeny (when economic weights for
      dairy cattle are of interest and terminal crossing in dairy
      herds is used))"
1
"Selection group for which gene flow is calculated
   (...)"
1
"Data for mastitis incidence
   (0 are not available
    1 are available)
3
"Quota for milk market
   (...)"
1
"Option for the calculation of the milk price
   (...)"
10
"Number of reproductive cycles (should be in the range from 4 to 15)"
```

As stated above for PARA.TXT, there are also certain dependencies between the parameters in the parameter file PARAD.TXT and further parameters in the data input files which must be taken into account. The following paragraphs list some important dependencies.

4.1.3.1 Consequences of changing the parameter Crossbreeding in the system

If there is no crossbreeding in the system ($cb = 0$), the option for calculating economic weights is automatically set to zero ($ewopt = 0$) independent of the value given in PARAD.TXT. Furthermore, the proportion of dairy cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$) mated with beef bulls ($pcross[i]$, read from INPUT07.TXT) and the proportion of dairy heifers mated with beef bulls ($pcrossh$, read from INPUT11.TXT) will be automatically set to zero. In input file INPUT27.TXT, the number of age classes for beef sires ($acsb$) and the number of age classes for cross-bred dams ($acdc$) must be both zero for systems without crossbreeding, otherwise an error message will occur when running the program and the program will stop.

4.1.3.2 Consequences of changing the parameter Utilisation of cross-bred female calves which are not needed for replacement'

Check always the following input parameter from input file INPUT23.TXT to be in accordance with the given option:

- Exported cross-bred female calves as proportion of reared cross-bred female calves

4.1.3.3 Consequences of changing the parameter 'Option for calculating economic weights'

In the file PARAD.TXT, the 'Selection group for which gene flow is calculated' must be in agreement with the option for calculating economic weights. Furthermore, you have to consider the values for the

- Vector of females mated with beef bulls as proportion of females mated in reproductive cycles 0 to $LL-1$ in input file INPUT07.TXT

and for

- Dairy heifers mated with beef bulls as proportion of all mated dairy heifers in input file INPUT11.TXT.

4.1.3.4 Consequences of changing the parameter 'Selection group for which gene flow is calculated'

This parameter must be in accordance with the 'Option for calculating economic weight' in PARAD.TXT and with the values of the two quantities from input files INPUT07.TXT and INPUT11.TXT as given above in Section 4.1.3.3.

4.1.3.5 Consequences of changing the parameter 'Data for mastitis incidence'

For option 1 of this parameter data from input files INPUT29.TXT and INPUT30.TXT must be available. If option zero is used, these two files are not read and you need not care about the values given in these files.

4.1.3.6 Consequences of changing the parameter 'Number of reproductive cycles'

When changing the number of lactations (reproductive cycles) take care to change all other input parameters in the appropriate way, especially in INPUT07.TXT, INPUT27.TXT and INPUT29.TXT.

4.2 Data input files for program EWBC (Production Systems 1 to 3)

A survey of data input files for all Production Systems is given in Table 4.1. Input files for Production Systems 1 to 3 are needed for running the program EWBC, input files for Production System 4 are needed for running the program EWDC. The latter are treated with in the following Section 4.3. At the beginning of each input file a comment is placed starting with /* and ending with */. The program recognises the slash (/) as the beginning and the end of the comment. When changing this text, do not use slashes within the comment (stars can be used within the comment).

Table 4.1: Survey of input files for Production Systems (PS) 1 to 4

Input file	PS1	PS2	PS3	PS4	Remark
INPUT01.TXT	x	x	x		
INPUT02.TXT	x	x	x		
INPUT03.TXT	x	x	x		
INPUT04.TXT	x	x	x		
INPUT05.TXT	x				
INPUT06.TXT	x	x	x		
INPUT07.TXT				x	
INPUT08.TXT	x	x	x		
INPUT09.TXT	x	x	x		only for variant 2 of feedlot (see Section 4.1.1.3)
INPUT10.TXT	x	x	x		only for variant 1 of feedlot (see Section 4.1.1.3)
INPUT11.TXT				x	
INPUT12.TXT				x	
INPUT13.TXT	x	x			
INPUT14.TXT			x		
INPUT15.TXT				x	
INPUT16.TXT	x	x	x		
INPUT17.TXT	x	x	x		only for variant 1 of feedlot (see Section 4.1.1.3)
INPUT18.TXT	x	x	x		only for variant 2 of feedlot (see Section 4.1.1.3)
INPUT19.TXT	x	x	x		only if the parameters of the lactation curve are calculated by the program (see Section 4.1.1.7)
INPUT20.TXT	x	x	x		only if the parameters of the lactation curve are read in (see Section 4.1.1.7)
INPUT21.TXT				x	
INPUT22.TXT				x	
INPUT23.TXT				x	
INPUT24.TXT				x	
INPUT25.TXT				x	
INPUT26.TXT	x	x	x		
INPUT27.TXT				x	
INPUT28.TXT				x	
INPUT29.TXT				x	only if data for mastitis are available
INPUT30.TXT				x	only if data for mastitis are available
FROM1_3.TXT				(x)	needed only in case that there is a transfer of data between programs EWBC and EWDC

4.2.1 Input file INPUT01.TXT

This file is necessary for Production Systems 1 to 3, the last parameter only for Production System 1. It includes input parameters describing the reproductive cycle in pasture systems through a year. All dates are given as two numbers (month, day) separated by one blank (or more blanks).

The following parameters are read from this file:

- Date of beginning pasture
- Date of ending pasture
- Date of starting the mating period
- Date of ending the first part of the mating period covering the first possibility of a female to conceive (previous date + approximately 20 days)
- Date of starting the second part of the mating period
- Date of ending the second part the mating period covering the second possibility of females to conceive (previous date + approximately 20 days)
- Date of starting the third part of the mating period
- Date of ending the third part of the mating period (end of the mating period) covering the third possibility of females to conceive (previous date + approximately 20 days)
- Date of weaning calves
- Starting date for the test of bulls (only needed for Production System 1)

4.2.2 Input file INPUT02.TXT

This file is necessary for Production Systems 1 to 3. It includes input parameters describing reproductive cycles of the cow herd in pasture systems. For each reproductive cycle, cows entering this cycle are differentiated in pregnant cows and cows not being pregnant. Losses of cows, culling etc. can be different in both groups. Two groups of cows are differentiated according to calving performance: cows with easy calving and cows with dystocia. Input parameters for losses of cows and calves, for insemination etc. can differ in both groups. The length of the vector (number of elements in the vector) is given by the number of reproductive cycles LL. Be careful when inserting the values, because the index may run from 1 to LL, from 2 to LL, from 1 to $LL-1$, from 2 to $LL-1$ etc.

The following parameters are read from this file:

- Vector of cow losses within reproductive cycles 1 to LL as proportion of cows entered the reproductive cycle as pregnant cows
- Vector of cow losses within reproductive cycles 2 to LL as proportion of cows entered the reproductive cycle as not pregnant cows
- Vector of cows culled within reproductive cycles 1 to LL for other health problems than dystocia as proportion of cows which entered these cycles as pregnant cows
- Vector of cows culled within reproductive cycles 2 to LL for other health problems than dystocia as proportion of cows which entered these cycles as not pregnant cows

- Vector of not pregnant cows which stayed in the herd for the next mating period as proportion of all not pregnant cows in reproductive cycles 1 to $LL-1$ that entered these cycles as pregnant cows
- Vector of not pregnant cows which stayed in the herd for the next mating period as proportion of all not pregnant cows in reproductive cycles 2 to $LL-1$ that entered these cycles as not pregnant cows
- Vector of cows having dystocia that were inseminated in 1st oestrus within reproductive cycles 1 to $LL-1$, respectively, as proportion of all mated cows having dystocia in these cycles (if natural mating is used only, set all elements of the vector 1)
- Vector of cows without dystocia that were inseminated in 1st oestrus within reproductive cycles 1 to $LL-1$ as proportion of all mated cows not having dystocia in these cycles (if natural mating is used only, set all elements of the vector 1)
- Vector of probabilities of abortion for cows conceived in reproductive cycles 1 to LL
- Vector of still born calves after dystocia as proportion of cows having dystocia in reproductive cycles 1 to LL
- Vector of still born calves after easy calving as proportion of cows having easy calving in reproductive cycles 1 to LL
- Vector of calves died to 48 hours as proportion of calves born alive after dystocia in reproductive cycles 1 to LL
- Vector of calves died to 48 hours as proportion of calves born alive after easy calving in reproductive cycles 1 to LL
- Vector of probabilities of calving score 2 when female is born in reproductive cycles 1 to LL
- Vector of probabilities of calving score 3 when female is born in reproductive cycles 1 to LL
- Vector of probabilities of calving score 4 when female is born in reproductive cycles 1 to LL
- Vector of probabilities of calving score 2 when male is born in reproductive cycles 1 to LL
- Vector of probabilities of calving score 3 when male is born in reproductive cycles 1 to LL
- Vector of probabilities of calving score 4 when male is born in reproductive cycles 1 to LL

4.2.3 Input file INPUT03.TXT

This file is necessary for Production Systems 1 to 3. It includes input parameters describing the cow herd in pasture systems.

The following parameters are read from this file:

- Conception rate of heifers in the 1st oestrus during the first part of mating period expressed as proportion of heifers mated in this oestrus

- Conception rate of heifers in the 2nd oestrus during the second part of mating period expressed as proportion of heifers not being pregnant after the 1st oestrus
- Conception rate of heifers in the 3rd oestrus during the third part of mating period expressed as proportion of heifers not being pregnant after the 2nd oestrus
- Conception rate of cows in the 1st oestrus during the first part of mating period for cows not having dystocia in reproductive cycles 1 to $LL-1$ expressed as proportion of cows mated in this oestrus
- Conception rate of cows in the 2nd oestrus during the second part of mating period for cows not having dystocia in reproductive cycles 1 to $LL-1$ expressed as proportion of cows not being pregnant after the 1st oestrus
- Conception rate of cows in the 3rd oestrus during the third part of mating period for cows not having dystocia in reproductive cycles 1 to $LL-1$ expressed as proportion of cows not being pregnant after the 2nd oestrus
- Length of pregnancy
- Average decrease in conception rate of cows after having dystocia in reproductive cycles 1 to LL
- Number of cows per bull for natural mating
- Number of re-inseminations per one AI
- Average length of the interval between calving and the beginning of the mating period
- Fat content in milk
- Protein content in milk
- Cow weight after second calving
- Mature weight of cows (= cow weight after 3rd calving)
- Weight gain for pregnancy (= loss of cow weight after calving) in reproductive cycles 1 to LL
- Dressing percentage of cows
- Mortality rate of cows after dystocia in reproductive cycles 1 to LL
- Losses of calves from 48 hours after calving to weaning in reproductive cycles 1 to LL (averaged over sexes)
- Losses of feed in winter feeding
- Losses of feed on the pasture
- Amount of dry matter produced per ha pasture
- Dry matter per kg summer feed ration for suckling calves (without milk)
- Dry matter content per kg winter feed ration of suckling calves (without milk)
- Dry matter per kg summer feed ration of cows

- Dry matter per kg winter feed ration of cows
- Net energy per kg dry matter of summer feed ration for cows
- Net energy per kg dry matter of summer feed ration (without milk) for suckling calves
- Net energy per kg dry matter of winter feed ration of cows
- Net energy per kg dry matter of winter feed ration (without milk) of suckling calves
- Protein per kg dry matter of summer feed ration for cows
- Protein per kg dry matter of summer feed ration (without milk) for suckling calves
- Protein per kg dry matter of winter feed ration for cows
- Protein per kg dry matter of winter feed ration (without milk) for suckling calves
- Correction coefficient for breed energy requirement for maintenance - dry cows
- Correction coefficient for breed energy requirement for maintenance - lactating cows
- Correction coefficient for energy requirement for maintenance according to technology - pasture
- Correction coefficient for energy requirement for maintenance according to technology - bind technology
- Correction coefficient for energy requirement for maintenance according to technology - free technology
- Amount of minerals per cow (including calf) and day
- Amount of water per cow (including calf) and day
- Amount of straw per cow (including calf) and day during the winter housing period
- Amount of dung per cow (with calf) and day during the winter housing
- Price per portion of semen for AI
- Price per re-insemination
- Price per kg fresh matter of winter feed ration for cows
- Price per kg fresh matter of winter feed ration for suckling calves (without milk)
- Price per kg fresh matter of summer feed ration for cows
- Price per kg fresh matter of summer feed ration for suckling calves (without milk)
- Price per kg dung
- Price per kg minerals for cows

- Price per kg minerals for replacement heifers
- Price per kg straw
- Price per l water
- Price for sold female weaned calf
- Price for sold male weaned calf
- Price per kg slaughter weight of cows in the base class for fleshiness and fat covering. [1]
- Ratio of price per kg slaughter weight of cows involuntarily culled to the price per kg slaughter weight of cows voluntarily culled
- Governmental financial support per weaned calf
- Governmental financial support per performance-tested cow and year
- Additional governmental financial support per cow and year
- Governmental financial support per culled cow
- Governmental financial support per exported male calf
- Fraction of performance-tested cows
- Cost for removing and rendering a dead cow
- Cost for removing and rendering a dead young animal
- Cost for veterinary treatment per cow and reproductive cycle (including calf to weaning)
- Veterinary cost connected with calving score 1
- Veterinary cost connected with calving score 2
- Veterinary cost connected with calving score 3
- Veterinary cost connected with calving score 4
- Stock-man hours connected with calving score 1
- Stock-man hours connected with calving score 2
- Stock-man hours connected with calving score 3
- Stock-man hours connected with calving score 4
- Cost per stock-man hour (needed for dystocia cost)
- Fixed cost per cow and day (including calf to weaning)
- Discount rate
- Barren heifers culled after their 1st mating period expressed as proportion of heifers not being pregnant in their 1st mating period

[1] The "base" class will mostly be the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient. These coefficients will be given in the input file INPUT16.TXT on page 70.

- Barren heifers culled after their 2nd mating period expressed as proportion of heifers not being pregnant in their 2nd mating period
- Female calves sold expressed as proportion of surplus female calves[2]
- Male calves sold expressed as proportion of male weaned calves
- Proportion of weaned male calves which are performance tested
- Fattened castrates expressed as proportion of male calves determined for fattening
- Proportion of surplus female calves for fattening[3]

4.2.4 Input file INPUT04.TXT

This file is necessary for Production Systems 1 to 3 if natural mating is performed. It includes input parameters referring to breeding bulls kept in the cow herd for natural mating. The first two numbers in the file are ignored in Production System 1.

The following parameters are read from this file:

- Age of breeding bulls at purchase for the herd (only for Systems 2 to 3)
- Weight of breeding bulls at purchase for the herd (only for Systems 2 to 3)
- Productive lifetime of breeding bulls in numbers of reproductive cycles of cows
- Age of breeding bulls at reaching mature body weight
- Mature body weight of bulls used in the herd
- Dry matter per kg summer feed ration for breeding bulls in the herds
- Dry matter per kg winter feed ration for breeding bulls in the herds
- Net energy content per kg dry matter of summer feed ration for breeding bulls in the herds
- Net energy content per kg dry matter of winter feed ration for breeding bulls in the herds
- Protein content per kg dry matter of summer feed ration in breeding bulls in herds
- Protein content per kg dry matter of winter feed ration in breeding bulls in herds
- Price per kg fresh matter of winter feed ration for breeding bulls in the herds
- Price per kg fresh matter of summer feed ration for breeding bulls in the herds
- Amount of minerals per day and breeding bull
- Price per kg minerals for breeding bulls

[2] In systems 1 and 2, the sum of the folling input parameters must be one: Female calves sold expressed as proportion of surplus female calves, Female calves for fattening expressed as proportion of surplus female calves, Pregnant heifers sold expressed as proportion of surplus female calves (INPUT13.TXT) and Breeding heifers sold before mating expressed as proportion of surplus female calves (INPUT13.TXT). In system 3, the first two parameters must sum to one.

[3] See footnote 2.

- Amount of straw per breeding bull in the herd in winter housing per day
- Amount of dung per breeding bull in the herd in winter housing per day
- Amount of water per day and breeding bull
- Average price per breeding bull purchased for natural mating
- Cost for veterinary treatment per breeding bull in the herd per reproductive cycle
- Fixed cost per breeding bull in the herd per day
- Average price per kg carcass weight of culled (old) breeding bulls

4.2.5 Input file INPUT05.TXT

This file is necessary only for Production System 1. It includes input parameters referring to performance tested breeding bulls. The feed rations as well as other costs refer to three time periods. The first period is before the test when the weaned calves are getting used to the intensive feed ration. The second period is the test with a fixed length, and the third period, in which the exterior and sperm quality is proved, is from the test end to the selection and selling of bulls.

The following parameters are read from this file:

- Daily gain of bulls in test
- Length of the test
- Days from the end of the test to selling bulls
- Proportion of bulls selected from the bulls tested at station
- Price per kg fresh matter of feed ration for breeding bulls before test
- Price per kg fresh matter of feed ration for breeding bulls in test
- Price per kg fresh matter of feed ration for breeding bulls after test
- Protein content per kg dry matter of feed ration for breeding bulls before test
- Protein content per kg dry matter of feed ration for breeding bulls in test
- Protein content per kg dry matter of winter feed ration for breeding bulls after test
- Net energy content per kg dry matter of feed ration for breeding bulls before test
- Net energy content per kg dry matter of feed ration for breeding bulls in test
- Net energy content per kg dry matter of feed ration for breeding bulls after test
- Dry matter per kg feed ration for breeding bulls before test
- Dry matter per kg feed ration for breeding bulls in test
- Dry matter per kg feed ration for breeding bulls after test
- Amount of dung per breeding bull at station per day

- Amount of straw per breeding bull at station per day
- Cost for veterinary treatment per bull at test station till selling
- Fixed costs per breeding bull on the test station per day
- Governmental support per bull on test station per day
- Average price for selected bulls at selling

4.2.6 Input file INPUT06.TXT

This file is necessary for Production Systems 1 to 3. It includes input parameters mainly connected with the progeny testing system for beef bulls.

The following parameters are read from this file:

- Age of calves at first weighing (first control)
- Age of calves at second weighing (second control)
- Age of calves at third weighing (third control)
- Weight of female calves at first weighing
- Weight of male calves at first weighing
- Weight of male calves at second weighing
- Weight of male calves at third weighing
- Weight of female calves at second weighing
- Weight of female calves at third weighing
- Weight of female calves at birth
- Weight of male calves at birth
- Mature weight of bulls used in the herd

4.2.7 Input file INPUT08.TXT

This file is necessary for Production Systems 1 to 3, for both variants of fattening. It includes input parameters valid for both variants of fattening. Furthermore, this file covers parameters for fattening bulls that are expected to be always intensively fattened independently on the variant for fattening of heifers or castrates.

The coefficients for price decrease of involuntarily culled animals are the ratios between the price per kg slaughter weight of involuntarily culled animals and the price per kg slaughter weight of animals that reached the given fixed slaughter weight. Losses of animals are given as number of animals died[4] during the fattening period expressed as proportion of the number of animals that entered fattening. Dressing percentage is expressed as ratio of the carcass weight and live weight of animals at slaughter.

If all surplus weaned calves are sold, the parameters connected exclusively with fattening are ignored in the calculations. But some of the parameters (as dressing percentage, price for slaughter animals, number of classes for fleshiness and fat covering) will be needed in each calculation, as there will be always culled heifers and bulls in the cow herd.

The following parameters are read from this file:

[4]For simplicity of the calculation, it is assumed that animals died in the middle of the time period under consideration. The same was assumed for animals slaughtered for health problems.

- Daily gain of bulls in intensive fattening
- Live weight of bulls at slaughter in intensive fattening
- Dressing percentage of bulls
- Dressing percentage of castrates
- Dressing percentage of heifers
- Dressing percentage of bulls not reaching slaughter weight as proportion of dressing percentage of bulls reaching slaughter weight
- Number of fattened bulls slaughtered before reaching slaughter weight expressed as proportion of the total number of fattened bulls
- Losses of bulls in intensive fattening period
- Amount of water per day and animal in intensive fattening
- Amount of dung per animal and day in intensive fattening
- Amount of straw per animal and day in intensive fattening
- Dry matter per kg feed ration for fattened bulls
- Net energy content per kg dry matter of feed ration for fattened bulls
- Protein content per kg dry matter of feed ration for fattened bulls
- Price per kg fresh matter of feed ration for fattened bulls
- Losses of feed in intensive fattening
- Price per kg slaughter weight of bulls in the base class[5]
- Coefficient for price decrease for bulls involuntarily culled
- Cost for veterinary treatment per animal in intensive fattening
- Fixed cost per animal and day in intensive fattening
- Number of classes for fleshiness
- Number of classes for fat covering

4.2.8 Input file INPUT09.TXT

This file is necessary only for extensive fattening (variant 2 for fattening - see Section 4.1.1.3) of heifers and castrates in Production Systems 1 to 3. If no castrates are fattened the input parameters referring to castrates will be ignored by the program.

Three time periods are differentiated in fattening. The first period is the winter feeding period after weaning, the second one is summer feeding usually only on pasture, and the third period is an intensive feeding period after pasture. The third period is needed only if the animals do not reach the required slaughter weight at the end of the pasture period. Coefficients for price decrease of involuntarily culled animals are the ratios of the price per kg slaughter weight of involuntarily culled

[5] The "base" class will mostly be the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient. These coefficients will be given in the input file INPUT16.TXT on page 70.

animals and the price per kg slaughter weight of animals that reached the required fixed slaughter weight.

Losses of animals are defined as animals died[6] during the fattening period as proportion of all animals entering fattening.

The following parameters are read from this file:

- Daily gain of castrates in the winter period after weaning in extensive fattening
- Daily gain of castrates in the summer period on pasture
- Daily gain of castrates in the intensive fattening period after pasture
- Daily gain of heifers in the winter period after weaning in extensive fattening
- Daily gain of heifers in the summer period on pasture
- Daily gain of heifers in the intensive fattening period after pasture
- Live weight of castrates at slaughter in extensive fattening
- Live weight of heifers at slaughter in extensive fattening
- Dressing percentage of castrates not reaching the slaughter weight as proportion of the dressing percentage of castrates reaching the required slaughter weight
- Dressing percentage of heifers not reaching the slaughter weight as proportion of the dressing percentage of heifers reaching the required slaughter weight
- Fattened castrates slaughtered before reaching the required slaughter weight expressed as proportion of all extensively fattened castrates
- Fattened heifers slaughtered before reaching the required slaughter weight expressed as proportion of all extensively fattened heifers
- Losses of castrates in extensive fattening
- Losses of heifers in extensive fattening
- Dry matter per kg feed ration for fattening castrates after pasture
- Dry matter per kg feed ration for fattening heifers after pasture
- Dry matter per kg winter feed ration (first winter after weaning) for extensively fattened castrates
- Dry matter per kg winter feed ration (first winter after weaning) for extensively fattened heifers
- Dry matter per kg summer feed ration for extensively fattened castrates
- Dry matter per kg summer feed ration for extensively fattened heifers
- Net energy content per kg dry matter of feed ration for fattened castrates after pasture
- Net energy content per kg dry matter of feed ration for fattened heifers after pasture
- Net energy content per kg dry matter of summer feed ration for extensively fattened castrates

[6] see footnote 4 on page 62

- Net energy content per kg dry matter of summer feed ration for extensively fattened heifers
- Net energy content per kg dry matter of winter feed ration for extensively fattened castrates
- Net energy content per kg dry matter of winter feed ration for extensively fattened heifers
- Protein content per kg dry matter of feed ration in fattened castrates after pasture
- Protein content per kg dry matter of feed ration in fattened heifers after pasture
- Protein content per kg dry matter of summer feed ration in extensively fattened castrates
- Protein content per kg dry matter of summer feed ration in extensively fattened heifers
- Protein content per kg dry matter of winter feed ration in extensively fattened castrates
- Protein content per kg dry matter of winter feed ration in extensively fattened heifers
- Price per kg fresh matter of feed ration for fattened castrates after pasture
- Price per kg fresh matter of feed ration for fattened heifers after pasture
- Price per kg fresh matter in summer feed ration for extensively fattened castrates
- Price per kg fresh matter in summer feed ration for extensively fattened heifers
- Price per kg fresh matter in winter feed ration for extensively fattened castrates
- Price per kg fresh matter in winter feed ration for extensively fattened heifers
- Price per kg minerals for extensively fattened castrates
- Price per kg minerals for extensively fattened heifers
- Amount of minerals per day per extensively fattened castrate
- Amount of minerals per day per extensively fattened heifer
- Amount of water per castrate and day in extensive fattening
- Amount of water per heifer and day in extensive fattening
- Amount of dung per animal and day in extensive fattening in winter housing
- Amount of straw per animal and day in extensive fattening in winter housing
- Cost for veterinary treatment per animal in extensive fattening
- Fixed cost per animal and day in extensive fattening
- Coefficient for price decrease for castrates involuntarily culled

- Coefficient for price decrease for heifers involuntarily culled
- Governmental support per fattened animal
- Price per kg slaughter weight of extensively fattened castrates for the base class[7]
- Price per kg slaughter weight of extensively fattened heifers for the base class[8]

4.2.9 Input file INPUT10.TXT

This file is necessary for intensive fattening (option 1 for fattening) of heifers and castrates in Production Systems 1 to 3. If no castrates are fattened the input parameters referring to castrates will be ignored.

Coefficients for price decrease of involuntary culled animals are the ratios of the price per kg slaughter weight of involuntary culled animals and the price per kg slaughter weight of animals that reached the required fixed slaughter weight. Losses of animals are defined as animals died[9] during the fattening period as proportion of all animals entering fattening.

If all surplus weaned calves are sold, the parameters connected exclusively with fattening are ignored in the calculations. But some of the parameters (as dressing percentage, price for slaughter animals, number of classes for fleshiness and fatcovering) will be needed in each calculation, as there will be always culled heifers and bulls in the cow herd.

The following parameters are read from this file:

- Daily gain of castrates in intensive fattening
- Daily gain of heifers in intensive fattening
- Live weight of castrates at slaughter
- Live weight of heifers at slaughter
- Fattened castrates slaughtered before the required slaughter weight expressed as proportion of all intensively fattened castrates
- Fattened heifers slaughtered before the required slaughter weight expressed as proportion of all intensively fattened heifers
- Dressing percentage of castrates not reaching the slaughter weight as proportion of the dressing percentage of castrates reaching the required slaughter weight
- Dressing percentage of heifers not reaching the slaughter weight as proportion of the dressing percentage of heifers reaching the required slaughter weight
- Losses of castrates in intensive fattening
- Losses of heifers in intensive fattening
- Amount of water per day and castrate in intensive fattening
- Amount of water per day and heifer in intensive fattening

[7] The "base" class will mostly be the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient. These coefficients will be given in the input file INPUT18.TXT on page 71.

[8] see footnote 7

[9] see footnote 4 on page 62

- Dry matter per kg feed ration for intensively fattened castrates
- Dry matter per kg feed ration for intensively fattened heifers
- Net energy content per kg dry matter of feed ration for intensively fattened castrates
- Net energy content per kg dry matter of feed ration for intensively fattened heifers
- Protein content per kg dry matter of feed ration in intensively fattened castrates
- Protein content per kg dry matter of feed ration in intensively fattened heifers
- Price per kg fresh matter of feed ration for intensively fattened castrates
- Price per kg fresh matter of feed ration for intensively fattened heifers
- Price per kg slaughter weight of intensively fattened castrates for the base class[10]
- Price per kg slaughter weight of intensively fattened heifers for the base class[11]
- Coefficient for price decrease for castrates involuntarily culled
- Coefficient for price decrease for heifers involuntarily culled
- Governmental support per fattened animal

4.2.10 Input file INPUT13.TXT

This file is necessary for Production Systems 1 and 2 only. It includes input parameters referring to replacement heifers from weaning to calving or to selling. Selling of pregnant or not mated heifers is possible. If not enough female calves are reared for replacement the input parameters referring to purchased replacement heifers are to be filled in. The purchased replacements are assumed to be pregnant heifers.

The following parameters are read from this file:

- Daily gain of replacement heifers in the 1st summer season after weaning (after reaching the age of 1 year)
- Daily gain of replacement heifers in the 2nd winter season after weaning (after reaching the age of 1 year)
- Daily gain of replacement heifers in the 2nd summer season after weaning (after reaching the age of 2 years)
- Daily gain of replacement heifers in the 3rd winter season after weaning (after reaching the age of 2 years)
- Daily gain of replacement heifers in the 3rd summer season after weaning (after reaching the age of 3 years)
- Daily gain of replacement heifers in the 4th winter season after weaning (after reaching the age of 3 years)

[10] The "base" class will mostly be the best class. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient. These coefficients will be given in the input file INPUT17.TXT on page 70.

[11] see footnote 10

- Minimal live weight of heifers at first mating
- Phenotypic standard deviation of the weight of heifers at the first mating period after weaning (at an age of about 1 year)
- Losses in the rearing period of heifers (from weaning to conception)
- Heifers selected on health and exterior before mating as proportion of reared heifers
- Pregnant heifers sold expressed as proportion of surplus female calves[12]
- Breeding heifers sold before mating expressed as proportion of surplus female calves[13]
- Number of days from the average date of mating heifers to the date of culling of not pregnant heifers
- Days of pregnancy of a purchased (or sold) female for replacement
- Heifers mated in 1st oestrus within the mating period as proportion of mated heifers (set this value to 1 if only natural mating is used)
- Dry matter per kg summer feed ration for breeding heifers
- Dry matter per kg winter feed ration for breeding heifers
- Net energy content per kg dry matter of summer feed ration for replacement heifers
- Net energy content per kg dry matter of winter feed ration for replacement heifers
- Protein content per kg dry matter of summer feed ration in replacement heifers
- Protein content per kg dry matter of winter feed ration in replacement heifers
- Price per kg fresh matter of winter feed ration for replacement heifers
- Price per kg fresh matter of summer feed ration for replacement heifers
- Amount of straw per replacement heifer in winter housing per day
- Amount of dung per replacement heifer in winter housing per day
- Amount of minerals per day and replacement heifer
- Amount of water per day and replacement heifer
- Costs for veterinary treatment per replacement heifer from weaning to calving
- Fixed costs from weaning to calving per replacement heifer and day
- Price per kg live weight of replacement heifers at purchase
- Price per kg live weight of not pregnant breeding heifers at selling

[12] In systems 1 and 2, the sum of the folling input parameters must be one: Female calves sold expressed as proportion of surplus female calves (INPUT03.TXT), Female calves for fattening expressed as proportion of surplus female calves (INPUT03.TXT), Pregnant heifers sold expressed as proportion of surplus female calves and Breeding heifers sold before mating expressed as proportion of surplus female calves. In system 3, the first two parameters must sum to one and the last two parameters are not defined.

[13] See footnote 12.

- Price per kg live weight of pregnant heifers at selling
- Average age of non-pregnant breeding heifers sold before the first mating period after their weaning
- Average age of non-pregnant breeding heifers sold between the first and second mating period after their weaning
- Proportion of non-pregnant breeding heifers sold before the first mating period after their weaning
- Proportion of non-pregnant breeding heifers sold between the first and second mating period after their weaning

4.2.11 Input file INPUT14.TXT

This file is necessary for Production System 3 only. It includes input parameters referring to the costs from purchase to calving for replacement females that are purchased at certain age, weight and days of pregnancy (days of pregnancy may be zero).

The following parameters are read from this file:

- Age of female for replacement at purchase
- Weight of female for replacement at purchase
- Days of pregnancy of purchased females for replacement
- Age of cows at first calving
- Weight of cows after 1st calving
- Weight of cows after 2nd calving
- Amount of dung in winter housing per replacement heifer and day
- Amount of minerals per replacement heifer and day
- Amount of straw in winter housing per replacement heifer and day
- Amount of water per replacement heifer and day
- Dry matter per kg summer feed ration for breeding heifers
- Dry matter per kg winter feed ration for breeding heifers
- Net energy content per kg dry matter of summer feed ration for replacement heifers
- Net energy content per kg dry matter of winter feed ration for replacement heifers
- Protein content per kg dry matter of summer feed ration for replacement heifers
- Protein content per kg dry matter of winter feed ration for replacement heifers
- Price per kg fresh matter of winter feed ration for replacement heifers
- Price per kg fresh matter of summer feed ration for replacement heifers
- Price per kg live weight of replacement heifers at purchase

- Fixed cost from weaning to calving per replacement heifer and day
- Cost for veterinary treatment for one replacement heifer from purchase to calving
- Heifers mated in 1st oestrus in the mating period as proportion of mated heifers (Set this value to 1 if only natural mating is used)

4.2.12 Input file INPUT16.TXT

This file contains input parameters for program EWBC (Production Systems 1 to 3) and both options 1 and 2 for fattening. For changing input data, change the number(s) in the matrices. Be careful when changing input parameters. Please notice that the description of the given matrix is posted under the matrix. The rows represent the commercial classes for fleshiness, the columns represent the classes for fat covering. The matrices of coefficients of carcass prices show the ratio of the price per kg carcass in the given class to the price in the base class. The price of the base class is an input parameter in the input files INPUT03.TXT and INPUT08.TXT (see Sections 4.2.3 and 4.2.7, respectively).

The following parameters are read from this file:

- Matrix *Pb* - proportions of bull carcasses in commercial classes for fleshiness and fat covering
- Matrix *Pc* - proportions of cow carcasses in commercial classes for fleshiness and fat covering
- Matrix *Prb* - coefficients of carcass prices in commercial classes for fleshiness and fat covering for bulls relative to the base class (insert value 1 for the base class)
- Matrix *Prc* - coefficients of carcass prices in commercial classes for fleshiness and fat covering for cows relative to the base class (insert value 1 for the base class)

Example: A short example will be given. Assume that there are three classes for fleshiness (1,2,3) and two classes for fat covering (1,2). Let us write the prices for bulls (in MU per kg slaughter weight) in the individual classes as matrix where the three rows refer to the three classes for fleshiness and the three columns to the classes for fat covering:

$$\begin{pmatrix} 50 & 48 \\ 45 & 42 \\ 40 & 38 \end{pmatrix}$$

Assume the combination of the first class for fleshiness and the first class for fat covering is considered as base class (with the value 50). Then the elements of matrix *Prb* are simply obtained by dividing all elements of the matrix of prices by this value 50:

$$\mathbf{Prb} = \begin{pmatrix} 1 & 0.96 \\ 0.90 & 0.84 \\ 0.80 & 0.76 \end{pmatrix}$$

4.2.13 Input file INPUT17.TXT

This file contains input parameters for Production Systems 1 to 3, only for option 1 for fattening. For changing input data, change the number(s) in the matrices. Be careful when changing input parameters. Please notice that the description of

the given matrix is posted under the matrix. The rows represent the commercial classes for fleshiness, the columns represent the classes for fat covering. The matrix of coefficients of carcass prices shows the ratio of the price per kg carcass in the given class to the price in the base class. The price of the base class is an input parameter in the input file INPUT10.TXT (see Section 4.2.9).

The following parameters are read from this file:

- Matrix Ph - proportions of heifer carcasses in commercial classes for fleshiness and fat covering
- Matrix Pcs - proportions of castrate carcasses in commercial classes for fleshiness and fat covering
- Matrix Prh - coefficients of carcass prices in commercial classes for fleshiness and fat covering for heifers relative to the base class
- Matrix Prcs - coefficients of carcass prices in commercial classes for fleshiness and fat covering for castrates relative to the base class

See also example in the section for input file INPUT16.TXT on the previous page.

4.2.14 Input file INPUT18.TXT

This file contains input parameters for Production Systems 1 to 3, only for option 2 of fattening. The parameters are the same as in INPUT17.TXT (see Section 4.2.13). The price of the base class is an input parameter in the input file INPUT09.TXT (see Section 4.2.8). See also example in the section for input file INPUT16.TXT on the preceding page.

4.2.15 Input file INPUT19.TXT

This file contains two parameters of the lactation curve. They are needed for Production Systems 1 to 3. The file is only read if the parameters are calculated according to Fox et al. [4]. For details see Section 2.3.1.

The two parameters are:

- Peak milk yield in kg per day (at the pasture with suckling calf)
- Expected milk production level of the herd (1 - lowest, 9 - highest)

4.2.16 Input file INPUT20.TXT

This file contains parameters for the lactation curve. The file is needed for Production Systems 1 to 3. The file is only read if the parameters are not calculated according to Fox et al. [4]. The parameters are parameters of the Wood function ([24], see equation (2.4) in Section 2.3).

The following parameters are read from this file:

- Parameter a for two year old cows
- Parameter a for three year old cows
- Parameter a for four year old cows
- Parameter a for mature cows
- Parameter b for two year old cows

- Parameter b for three year old cows
- Parameter b for four year old cows
- Parameter b for mature cows
- Parameter c for two year old cows
- Parameter c for three year old cows
- Parameter c for four year old cows
- Parameter c for mature cows

4.2.17 Input file INPUT26.TXT

This file is needed for Production Systems 1 to 3 and for both options 1 and 2 of fattening. It contains input parameters for gene flow(see Section 2.8). For changing input data, change the number(s). Be careful when changing input parameters. Please notice that the description of the given parameter or vector is posted under the number(s). The following parameters are read:

- Number of age classes for sires
- Number of age classes for dams (number of reproductive cycles + age at calving in years - 1)
- Number of the sex-age class for which the gene flow will be calculated (see Section 2.8 for further explanation)
- Length of the investment period
- Proportion of genes from individual age classes of sires in the male progeny (path sires to sires, the numbers must sum to 0.5)
- Proportion of genes from individual age classes of sires in the female progeny (path sires to dams) or in slaughter progeny (the numbers must sum to 0.5)
- Proportion of genes from individual age classes of dams in the male progeny (path dames to sires, the numbers must sum to 0.5)

4.3 Data input files for program EWDC (Production System 4)

4.3.1 Input file INPUT07.TXT

This file includes input parameters describing reproductive cycles (lactations) of the dairy cow herd. In each reproductive cycle, cows can be mated to dairy bulls or to beef bulls. Losses of cows, culling, conception rate and abortion are assumed to be the same in both groups of cows, but differences are possible for dystocia occurrence. Therefore altogether four groups of cows are differentiated according to calving performance: cows with easy calving and cows with dystocia in both mating types. The input parameters for losses of cows and calves, for conception rate etc. can differ between the groups with and without dystocia occurrence.

All input data are arranged in the following way: each parameter takes three rows. The vector of its values for reproductive cycles 1 to LL or 1 to $LL-1$ stands in the first row, the string expression in the second row describes the parameter and

the last string in the third row contains the units of the parameter. This field may be an empty string.

Some of the probabilities of calving score x at the end of the input file may be of no concern. For example, if the number of classes for calving performance is 4, all values for calving scores 5 and 6 are ignored. If there is no crossbreeding in the system, the calving scores for cross-bred animals are not read. Do not omit rows with unnecessary information in the input file. The program will skip the inputs which are not needed.

The following parameters are given in the file:

- Vector of cow losses within reproductive cycles 1 to LL as proportion of cows entered the reproductive cycle
- Vector of cows culled within reproductive cycles 1 to LL for other health problems than dystocia as proportion of cows entered the reproductive cycle
- Vector of cows culled within reproductive cycles 1 to LL for low milk production as proportion of cows entered the reproductive cycle
- Vector of probability of abortion for cows conceived in reproductive cycles 1 to LL
- Vector of still born calves after dystocia as proportion of cows having dystocia in reproductive cycles 1 to LL
- Vector of still born calves after easy calving as proportion of cows having easy calving in reproductive cycles 1 to LL
- Vector of calves died to 48 hours from calves born alive after dystocia in reproductive cycles 1 to LL
- Vector of calves died to 48 hours from calves born alive after easy calving in reproductive cycles 1 to LL
- Vector of females mated with beef bulls as proportion of females mated in reproductive cycles 1 to $LL-1$
- Vector of conception rate after ith insemination for cows not having dystocia ($i = 1$ to $inmax$ where $inmax$ is the maximal number of inseminations for cows - see INPUT11.TXT on the next page)
- Vector of conception rate after ith insemination for heifers ($i = 1$ to $inmaxh$ where $inmaxh$ is the maximal number of inseminations for heifers - see INPUT11.TXT on the following page)
- Probability of calving score 2 when a pure-bred dairy female calf is born in reproductive cycles 1 to LL (see Section 2.6.3.1 for the definition of calving scores)
- Probability of calving score 2 when a pure-bred dairy male calf is born in reproductive cycles 1 to LL
- Probability of calving score 3 when a pure-bred dairy female calf is born in reproductive cycles 1 to LL
- Probability of calving score 3 when a pure-bred dairy male calf is born in reproductive cycles 1 to LL
- Probability of calving score 4 when a pure-bred dairy female calf is born in reproductive cycles 1 to LL

- Probability of calving score 4 when a pure-bred dairy male calf is born in reproductive cycles 1 to LL
- Probability of calving score 5 when a pure-bred dairy female calf is born in reproductive cycles 1 to LL
- Probability of calving score 5 when a pure-bred dairy male calf is born in reproductive cycles 1 to LL
- Probability of calving score 6 when a pure-bred dairy female calf is born in reproductive cycles 1 to LL
- Probability of calving score 6 when a pure-bred dairy male calf is born in reproductive cycles 1 to LL
- Probability of calving score 2 when a cross-bred (beef x dairy) female calf is born in reproductive cycles 1 to LL
- Probability of calving score 2 when a cross-bred (beef x dairy) male calf is born in reproductive cycles 1 to LL
- Probability of calving score 3 when a cross-bred (beef x dairy) female calf is born in reproductive cycles 1 to LL
- Probability of calving score 3 when a cross-bred (beef x dairy) male calf is born in reproductive cycles 1 to LL
- Probability of calving score 4 when a cross-bred (beef x dairy) female calf is born in reproductive cycles 1 to LL
- Probability of calving score 4 when a cross-bred (beef x dairy) male calf is born in reproductive cycles 1 to LL
- Probability of calving score 5 when a cross-bred (beef x dairy) female calf is born in reproductive cycles 1 to LL
- Probability of calving score 5 when a cross-bred (beef x dairy) male calf is born in reproductive cycles 1 to LL
- Probability of calving score 6 when a cross-bred (beef x dairy) female calf is born in reproductive cycles 1 to LL
- Probability of calving score 6 when a cross-bred (beef x dairy) male calf is born in reproductive cycles 1 to LL

4.3.2 Input file INPUT11.TXT

This file includes the following input parameters describing the dairy cow herd which are arranged in the following way: parameters for reproduction, growth, mortality, feeding, prices and costs:

- Number of classes for calving score
- For defining dystocia give the lowest score of calving performance which is considered to be dystocia. For example, if there are scores 1 to 5 and scores 3 to 5 will be considered as dystocia your input will be 3.
- Gestation length
- Average interval between calving and first insemination

- Average interval between two subsequent inseminations
- Number of days dry
- Maximal number of inseminations per cow after calving
- Maximal number of inseminations per heifer
- Number of re-inseminations per AI
- Decrease in conception rate of cows after dystocia averaged over reproductive cycles 1 to LL
- Culling rate of cows after dystocia
- Genetic standard deviation for lactational milk yield
- Fat content in milk
- Protein content in milk
- Mature weight of dairy cows (weight of cows after 3rd calving)
- Mature weight of beef cows of the same breed the bulls of which are used for terminal crossing (weight of cows after 3rd calving)
- Weight gain for pregnancy (= loss of cow weight after calving) averaged over reproductive cycles 1 to LL
- Average daily gain of cows in the 1st reproductive cycle
- Average number of days between calving and culling cows due to dystocia
- Dressing percentage of cows
- Losses of feed in cow herds or in rearing of young animals
- Losses of feed in fattening
- Dry matter per kg feed for cows (average feed ration through the whole calving interval)
- Net energy per kg dry matter of feed ration for cows
- Protein per kg dry matter of feed ration for cows
- Correction coefficient for breed energy requirement for maintenance - dry cows
- Correction coefficient for breed energy requirement for maintenance - lactating cows
- Correction coefficient for energy requirement for maintenance according to technology - pasture
- Correction coefficient for energy requirement for maintenance according to technology - bind technology
- Correction coefficient for energy requirement for maintenance according to technology - free technology
- Amount of water per cow and day
- Amount of straw per cow and day

- Amount of dung per cow and day
- Price per kg fresh matter of feed ration for cows
- Price per kg dung
- Price per kg straw
- Price per l water
- Price of one portion of semen from AI dairy bulls including external labour for insemination
- Price per re-insemination from dairy bulls including external labour for insemination
- Price of one portion of semen from AI beef bulls including external labour for insemination
- Price per re-insemination from beef bulls including external labour for insemination
- Price per kg slaughter weight of cows in the base class[14] for carcass grading
- Ratio of price per kg slaughter weight of cows involuntarily culled to the price per kg slaughter weight of cows voluntarily culled
- Cost for removing and rendering of a dead cow
- Cost for veterinary treatment per cow and reproductive cycle
- Veterinary cost connected with calving score 1
- Veterinary cost connected with calving score 2
- Veterinary cost connected with calving score 3
- Veterinary cost connected with calving score 4
- Veterinary cost connected with calving score 5
- Veterinary cost connected with calving score 6
- Stock-man hours connected with calving score 1
- Stock-man hours connected with calving score 2
- Stock-man hours connected with calving score 3
- Stock-man hours connected with calving score 4
- Stock-man hours connected with calving score 5
- Stock-man hours connected with calving score 6
- Cost per stock-man hour (needed for dystocia cost)
- Variable costs for milk when increasing the milk yield above average
- Fixed cost per cow and day

[14] The "base" class may be the most frequent class or the best class for example. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient. These coefficients will be given in the input file INPUT24.TXT on page 82.

- Discount rate
- Governmental financial support per kg milk
- Governmental financial support per cow and year (e.g. for culled cows)
- Governmental financial support per cow in performance test and year
- Governmental financial support per exported male calf
- Governmental financial support per fattened animal
- Proportion of cows performance tested
- Dairy heifers mated with beef bulls as proportion of all mated dairy heifers (this parameter is read only if there is crossbreeding in the system)

4.3.3 Input file INPUT12.TXT

This file is necessary for program EWDC only if reared breeding male calves are kept to higher age at farms, that means stay at farms after the rearing period of calves till their selling to AI stations. The following parameters are read:

- Daily gain of bulls from the end of the rearing period of calves till selling
- Price per kg fresh matter of feed ration for breeding bulls from the end of the rearing period of calves till selling
- Protein content per kg dry matter of feed ration for breeding bulls from the end of the rearing period of calves till selling
- Net energy content per kg dry matter of feed ration for breeding bulls from the end of the rearing period of calves till selling
- Dry matter per kg feed ration for breeding bulls from the end of the rearing period of calves till selling
- Amount of dung per breeding bull per day
- Amount of straw per breeding bull per day
- Amount of water per breeding bull per day
- Cost for veterinary treatment per bull from the end of rearing period of calves till selling
- Fixed costs per breeding bull per day
- Governmental support per breeding bull per day

4.3.4 Input file INPUT15.TXT

This file includes input parameters connected with progeny. Two types of calving (after pure-bred and cross-bred mating) are distinguished giving two types of progeny (pure-bred and cross-bred). The first number refers to pure-bred (dairy) progeny and must be always given. The second number is for cross-bred progeny and can be omitted if there is no crossbreeding in the system. If a second number is given in a system without crossbreeding, this number is ignored and its value is of no importance (that means you can insert any value for it). Here is a list of the parameters read from this file:

- Weight of female calves at birth
- Weight of male calves at birth
- Age of calves at the end of the first feeding period
- Age of calves at the end of the rearing period
- Age of female calves sold
- Age of male calves sold
- Daily gain of female calves in the rearing period
- Daily gain of male calves in the rearing period
- Age of male breeding calves at selling to the performance test stations
- Weight of heifers at 1st mating
- Daily gain of replacement heifers from the end of the rearing period to 1st mating
- Daily gain of replacement heifers from the 1st mating to calving (without foetus)
- Days from mating heifer to slaughter because of no pregnancy
- Age of unpregnant breeding heifers at selling
- Age of pregnant heifers at selling
- Daily gain of heifers in fattening
- Daily gain of bulls in fattening
- Daily gain of castrates in fattening
- Dressing percentage of heifers
- Dressing percentage of bulls
- Dressing percentage of castrates
- Losses of calves in the rearing period
- Proportion of male calves alive at 48 hours after birth that are determined for selling outside of the evaluated production system
- Proportion of male calves alive at 48 hours after birth that are sold as breeding males (e.g. to test stations or AI stations)
- Fraction of castrates for fattening from male calves available for fattening
- Losses of bulls in fattening
- Fattened bulls slaughtered before reaching the slaughter weight as proportion of all fattened bulls
- Losses of castrates in fattening
- Fattened castrates slaughtered before reaching the slaughter weight as proportion of all fattened castrates

- Losses of heifers in fattening
- Fattened heifers slaughtered before reaching the slaughter weight as proportion of all fattened heifers
- Losses of heifers from the end of the rearing period to 1st insemination
- Heifers negatively selected before mating as proportion of reared heifers

4.3.5 Input file INPUT21.TXT

This file includes input parameters for nutrition and other costs for reared and fattened progeny and for cows. Two groups of progeny are differentiated: pure-bred dairy progeny and cross-bred progeny so that up to two numbers are given for each input. The first number refers to pure-bred (dairy) progeny and must be always given. The second number is for cross-bred progeny and can be omitted if there is no crossbreeding in the system. If the second number is given in a system without crossbreeding, this number is ignored and its value is of no importance (that means you can insert any value for it).

In each input, the first number is always for dairy progeny, the second number for cross-bred progeny. If cross-bred progeny does not exist the appropriate parameters will be ignored when reading data. The input parameters are:

- Dry matter per kg feed ration for reared calves in the first feeding period
- Net energy content per kg dry matter of feed ration for reared calves in the first feeding period
- Protein content per kg dry matter of feed ration for reared calves in the first feeding period
- Price per kg fresh matter of feed ration for reared calves in the first feeding period
- Dry matter per kg feed ration for reared calves in the second feeding period
- Net energy content per kg dry matter of feed ration for reared calves in the second feeding period
- Protein content per kg dry matter of feed ration for reared calves in the second feeding period
- Price per kg fresh matter of feed ration for reared calves in the second feeding period
- Amount of water per reared calf and day
- Amount of dung per reared calf and day
- Amount of straw per reared calf and day
- Cost for veterinary treatment per reared calf
- Fixed cost per reared calf and day
- Dry matter per kg feed ration for reared heifers
- Net energy content per kg dry matter of feed ration for reared heifers
- Protein content per kg dry matter of feed ration for reared heifers

- Price per kg fresh matter of feed ration for reared heifers
- Amount of water per reared heifer and day
- Amount of dung per reared heifer and day
- Amount of straw per reared heifer and day
- Cost for veterinary treatment per reared heifer from the end of rearing period to calving
- Fixed cost per reared heifer from the end of rearing period to calving and per day
- Dry matter per kg feed ration for fattened bulls
- Net energy content per kg dry matter of feed ration for fattened bulls
- Protein content per kg dry matter of feed ration in fattened bulls
- Price per kg fresh matter of feed ration in fattening of bulls
- Amount of water per bull and day in fattening
- Amount of dung per bull and day in fattening
- Amount of straw per bull and day in fattening
- Cost for veterinary treatment per bull in fattening
- Fixed cost per bull and day in fattening
- Dry matter per kg feed ration for fattened castrates
- Net energy content per kg dry matter of feed ration for fattened castrates
- Protein content per kg dry matter of feed ration in fattened castrates
- Price per kg fresh matter of feed ration in fattening of castrates
- Amount of water per castrate and day in fattening
- Amount of dung per castrate and day in fattening
- Amount of straw per castrate and day in fattening
- Cost for veterinary treatment per castrate in fattening
- Fixed cost per castrate and day in fattening
- Dry matter per kg feed ration for fattened heifers
- Net energy content per kg dry matter of feed ration for fattened heifers
- Protein content per kg dry matter of feed ration in fattened heifers
- Price per kg fresh matter of feed ration in fattening of heifers
- Amount of water per fattened heifer and day
- Amount of dung per heifer and day in fattening
- Amount of straw per heifer and day in fattening
- Cost for veterinary treatment per heifer in fattening

- Fixed cost per heifer and day in fattening
- Costs for removing and rendering of a dead young animal (replacement heifer or animal in fattening)
- Costs for removing and rendering of a dead calf in the rearing period
- Price of a female reared calf for selling (per kg live weight or per animal)
- Price of a male reared calf for selling (per kg live weight or per animal)
- Price of a male breeding calf sold to the test station or to A.I. station (per kg live weight or per animal)
- Price of a not pregnant breeding heifer at selling (per kg live weight or per animal)
- Price of a pregnant heifer at selling (per kg live weight or per animal)

4.3.6 Input file INPUT22.TXT

This file contains the parameters b, c and d for the lactation curve (2.5) for dairy cows:

- Average milk yield per cow and year
- Parameter b for the first lactation
- Parameter b for the second lactation
- Parameter b for third and higher lactations
- Parameter c for the first lactation
- Parameter c for the second lactation
- Parameter c for the third and higher lactations
- Parameter d for the first lactation
- Parameter d for the second lactation
- Parameter d for the third and higher lactations

4.3.7 Input file INPUT23.TXT

This file includes economic, management and biological input parameters. Equal values of the parameters are expected for both progeny groups (dairy and cross-bred progeny). If a difference occurs, insert the weighted average of the two values (weighted by the number of progeny in both groups). The parameters are:

- Coefficient for price decrease for heifers involuntarily culled
- Coefficient for price decrease for bulls involuntarily culled
- Coefficient for price decrease for castrates involuntarily culled
- Dressing percentage of heifers not reaching slaughter weight as proportion of dressing percentage of heifers reaching slaughter weight
- Dressing percentage of bulls not reaching slaughter weight as proportion of dressing percentage of bulls reaching slaughter weight

- Dressing percentage of castrates not reaching slaughter weight as proportion of dressing percentage of castrates reaching slaughter weight
- Price per kg slaughter weight of heifers in the base class for carcass grading[15]
- Price per kg slaughter weight of bulls in the base class for carcass grading[16]
- Price per kg slaughter weight of castrates in the base class for carcass grading[17]
- Sold cross-bred female calves as proportion of reared cross-bred female calves
- Number of commercial classes for fleshiness
- Number of commercial classes for fat covering
- Slaughter weight of pure-bred beef bulls at the end of fattening
- Slaughter weight of pure-bred beef heifers at the end of fattening
- Slaughter weight of pure-bred beef castrates at the end of fattening
- Slaughter weight of pure-bred dairy heifers at the end of fattening
- Slaughter weight of pure-bred dairy bulls at the end of fattening
- Slaughter weight of pure-bred dairy castrates at the end of fattening

4.3.8 Input file INPUT24.TXT

In its first part, this input file contains matrices describing the distribution of the pure-bred dairy progeny over the individual commercial classes for fleshiness and fat covering. In the second part, the file contains the matrices of coefficients of carcass prices which are valid both for pure-bred and cross-bred animals. Please notice that the description of the given matrix is posted *under* the matrix. The rows represent the commercial classes for fleshiness, the columns the classes for fat covering. The matrices of coefficients of carcass prices show the ratio of the price per kg carcass in the given class to the price in the base class. The price of the base class is an input parameter in the input files INPUT11.TXT and INPUT23.TXT (see Sections 4.3.2 and 4.3.7, respectively). The matrices are as follows:

- Matrix Pb_p: proportions of bull carcasses in commercial classes for fleshiness and fat covering
- Matrix Ph_p: proportions of heifer carcasses in commercial classes for fleshiness and fat covering
- Matrix Pcs_p: proportions of castrate carcasses in commercial classes for fleshiness and fat covering
- Matrix Pc_p: proportions of cow carcasses in commercial classes for fleshiness and fat covering
- Matrix Prb: coefficients of carcass prices in commercial classes for fleshiness and fat covering for bulls relative to the base class (insert value 1 for the base class)

[15] The "base" class may be the most frequent class or the best class, for example. The prices for all other classes are then calculated by multiplying the price of the base class with a coefficient. These coefficients will be given in the input file INPUT24.TXT on this page.

[16] see footnote 15

[17] see footnote 15

- Matrix Prh: coefficients of carcass prices in commercial classes for fleshiness and fat covering for heifers relative to the base class (insert value 1 for the base class)
- Matrix $Prcs$: coefficients of carcass prices in commercial classes for fleshiness and fat covering for castrates relative to the base class (insert value 1 for the base class)
- Matrix Prc: coefficients of carcass prices in commercial classes for fleshiness and fat covering for cows relative to the base class (insert value 1 for the base class)

See example in Section 4.2.12 on page 70.

4.3.9 Input file INPUT25.TXT

This input file contains matrices describing the distribution of the cross-bred (beef x dairy) progeny over the individual commercial classes for fleshiness and fat covering. The file is only read if there is crossbreeding in the system, otherwise it is ignored. The matrices have the same structure as in input file INPUT24.TXT (see Section 4.3.8). The matrices are as follows:

- Matrix Pb_c - proportions of bull carcasses in commercial classes for fleshiness and fat covering
- Matrix Ph_c - proportions of heifer carcasses in commercial classes for fleshiness and fat covering
- Matrix Pcs_c - proportions of castrate carcasses in commercial classes for fleshiness and fat covering

4.3.10 Input file INPUT27.TXT

This file contains the input parameters for gene flow (see Section 2.8). The parameter 'Number of age classes for cross-bred dams' depends on the number of reproductive cycles in program EWBC. Modify this parameter in the appropriate way if necessary.

The parameters in the file are:

- Number of age classes for dairy sires
- Number of age classes for dairy dams ($LL - 1+$ age at calving in years[18])
- Number of age classes for beef sires
- Number of age classes for cross-bred dams (Calculate as: Number of reproductive cycles in System 3 + age at calving in years - 1)
- Number of the sex-age class for which the gene flow will be calculated
- Length of the investment period
- Proportion of genes from individual age classes of dairy sires in male progeny (path sires to sires, the numbers must sum to 0.5)
- Proportion of genes from individual age classes of dairy sires in female progeny (path sires to dams, the numbers must sum to 0.5)

[18]When calculating the age in years, round always up to the next full year. For example, 1.1 years should be rounded up to 2 years etc.

- Proportion of genes from individual age classes of dairy dams in male progeny (path dames to sires, the numbers must sum to 0.5)
- Proportion of genes from individual age classes of beef sires in cross-bred progeny (the numbers must sum to 0.5)

4.3.11 Input file INPUT28.TXT

This file contains parameters which are needed for the calculation of the milk price. According to the option for the calculation of the milk price (see Paragraph 4.1.1.14), different sets of parameters are read. The value of the parameters which are not read in the given run is of no impact on the results; they can be simply ignored. The parameters mainly refer to fat and protein content in milk and to somatic cell count or somatic cell score. A great variety of pricing systems can be parametrised by this file. The following input parameters are to be specified in dependence of the parameter *milkprice*, the option for the calculation of the milk price:

Part A

- Base price for milk (*prmilkb*). This is the milk price not taking into account the fat and protein content and the somatic cell score. Its value is read for $milkprice = 1, 3$ or 5. The base price for milk is set to zero if $milkprice =$ 2 or 4.

Part B The following part of the input file (until the next comment commencing with "/*") is read only if the option for the calculation of the milk price (*milkprice*) takes one of the following values: 3, 4 or 5.

- Parameter $nfat$ for the dependence of the milk price on the milk fat content. Insert -1 if the milk price does not depend on fat content. Insert 0 if the milk price depends linearly over the whole range on fat content (there is only one regression equation). Insert a positive integer (number of threshold values) if the dependence changes at one or more values (threshold values) of the fat content.
- Threshold values for milk fat. If $nfat$ takes values -1 or 0 insert zero. If $nfat > 0$ insert $nfat$ threshold values.
- Parameter *nprot* for the dependence of the milk price on the milk protein content. Insert -1 if the milk price does not depend on protein content. Insert 0 if the milk price depends linearly over the whole range on protein content (there is only one regression equation). Insert a positive integer (number of threshold values) if the dependence changes at one or more values (threshold values) of the protein content.
- Threshold values for milk protein. If *nprot* takes values -1 or 0 insert zero. If $nprot > 0$ insert *nprot* threshold values.
- Constants (intercepts), regression coefficients and reference values for fat content in individual classes. The whole range of the fat content is divided by the $nfat$ threshold values into $nfat + 1$ classes where the first class is the range between 0% and the first threshold value, the second class in the range between the first and the second threshold value, ..., and the last class is the range between the last threshold value and 100%. For all classes (rows in the matrix), three numbers have to be given. The first number b_0 is a constant (intercept). The second number b_1 is the regression coefficient. The third

number x_r is a reference value which is subtracted from the fat content. The regression equation has therefore the following form:

$$y = b_0 + b_1(x - x_r) \tag{4.1}$$

where x is the milk fat content and y is the value which is to be added to the basic milk price.

- Constants (intercepts), regression coefficients and reference values for protein content in individual classes. See explanations above.
- Phenotypic standard deviation for milk fat content
- Phenotypic standard deviation for milk protein content

Part C The next part of the input file is read only if the option for the calculation of the milk price (*milkprice*) takes one of the following values: 2, 4 or 5.

- Mean of somatic cell score in the dairy cow population
- Phenotypic standard deviation of somatic cell score in the dairy cow population
- Number of milk quality classes according to somatic cell count (this value is automatically set to 1 for $milkprice = 1$ or 3)
- Upper limits for somatic cell count in the individual milk quality classes (the 1st class being the best)

Part D The following vector of parameters is read for $milkprice = 2$ or 4:

- Vector of basic prices per kg milk in quality class i ($i = 0$ to $nSCC - 1$ where $nSCC$ is the number of milk quality classes according to somatic cell count)

Part E The last matrix of parameters is read only for $milkprice = 5$:

- Multiplicative and additive correction factors for milk quality classes on the basis of SCC. Two parameters must be given for each milk quality class. The first one is used to multiply the milk price calculated before and the second parameter is added to the milk price. For more details see Section 2.5.1.2 and the following examples.

Some examples will be given. Example 1 refers to Part A of the input file, examples 2 to 5 refer to Part B of the input file. Examples 6, 7 and 8 are for Parts C, D and E, respectively.

4.3.11.1 Example 1 for INPUT28.TXT for filling in Part A of the input file

Assume that the milk price does neither depend on the somatic cell count nor on the protein and/or the fat content. That means, the option for the calculation of the milk price (*milkprice*) is 1 in PARAD.TXT. Then the only parameter read from the file is the basic milk price (*prmilkb*). That means, only Part A of the file is relevant:

```
/* Input parameters for program EWDC (Production System 4):
Parameters for the calculation of the milk price.
For examples see the Manual.
MU: monetary unit */
```

```
8.10
"Base price for milk (is read if the option for the calculation of the milk price
takes one of the following values:  1, 3 or 5; for details see the manual.)"
"MU/kg"
```

The rest of the input file is ignored and it does not matter how it looks like.

4.3.11.2 Example 2 for INPUT28.TXT for filling in Part B of the input file

This is an example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price[19] (variable *milkprice*) takes one of the following values: 3, 4 or 5.

The pricing system looks as follows: There is a penalty of 1 MU (monetary unit) if the fat content is below 3.6%. This penalty does not depend on the fat content. Only the basic milk price[20] is paid if the fat content is between 3.6% and 3.9%.

For the fat content greater than 3.9%, 0.5 MU are paid for each additional per cent. That means, the parameter for the dependence of the milk price on the milk fat content takes the value 2 (two threshold values, 3.6% and 3.9%). There are three classes for regression with the following equations:

$$\begin{aligned} y &= -1 + 0(x - 0) = -1 \\ y &= 0 + 0(x - 0) = 0 \\ y &= 0 + 0.5(x - 3.9) = 0.5(x - 3.9) \end{aligned} \tag{4.2}$$

Therefore, in the first class, $b_0 = -1$, $b_1 = 0$ and $x_r = 0$. In the second class, all three parameters are zero and in the third class, $b_0 = 0$, $b_1 = 0.5$ and $x_r = 3.9$.

In a similar way, there is a penalty of 1 MU if the protein content is below 2.8%. Only the basic milk price is paid if the protein content is between 2.8% and 3.3%. For the protein content greater than 3.3%, 0.5 MU are paid for each additional per cent. That means, the parameter for the dependence of the milk price on the milk protein content takes also the value 2 and there are three classes for regression. The equations are similar as for fat content. In the first class, $b_0 = -1$, $b_1 = 0$ and $x_r = 0$. In the second class, all three parameters are zero and in the third class, $b_0 = 0$, $b_1 = 0.5$ and $x_r = 3.3$.

The standard deviations for fat and protein content are 0.45 and 0.213, respectively. Then the relevant part of the input file looks as follows:

```
/* Input parameters for program EWDC (Production System 4):
...  */
...
/* ...  */
2
"Parameter for the dependence of the milk price on the milk fat content..."
" "
3.6 3.9
"Threshold values for milk fat..."
"%"
2
"Parameter for the dependence of the milk price on the milk protein content ..."
" "
2.8 3.3
"Threshold values for milk protein..."
"%"
-1 0 0
0 0 0
```

[19] see Paragraph 4.1.1.14 on page 50

[20] The basic milk price is the first input parameter in INPUT28.TXT (*milkprice* = 3 or 5) or is calculated from the prices of the individual milk quality classes (*milkprice* = 4).

```
0 0.5 3.9
"Constants (intercepts), regression coefficients and reference values for fat content
in individual classes"
"MU/% fat"
-1 0 0
0 0 0
0 0.5 3.3
"Constants (intercepts), regression coefficients and reference values for protein con-
tent in individual classes"
"MU/% protein"
0.45
"Standard deviation for milk fat content"
"%"
0.213
"Standard deviation for milk protein content"
"%"
...
```

4.3.11.3 Example 3 for INPUT28.TXT for filling in Part B of the input file

This is a second example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price[21] (variable *milkprice*) takes one of the following values: 3, 4 or 5.

Assume that there is a basic milk price[22] paid for milk carrier (milk without fat and protein).

For each kg of milk fat, 141 MU is paid, that means 1.41 MU per per cent fat (= 10 g fat/kg milk). For each kg of milk protein, 226.1 MU is paid, that means 2.261 MU per per cent protein. Both for fat and protein content, the regression is over the whole range and there is no threshold value. The regression equation for fat content is:

$$y = 0 + 1.41(x - 0) = 1.41x \tag{4.3}$$

Therefore, $b_0 = 0$, $b_1 = 1.41$ and $x_r = 0$. For protein content we get

$$y = 0 + 2.261(x - 0) = 2.261x \tag{4.4}$$

so that $b_0 = 0$, $b_1 = 2.261$ and $x_r = 0$.

The appropriate part of the input file looks therefore as follows:

```
/* ...  */
...
/* ...  */
0
"Parameter for the dependence of the milk price on the milk fat content ..."
" "
0
"Threshold values for milk fat ..."
"%"
0
"Parameter for the dependence of the milk price on the milk protein content ..."
" "
0
"Threshold values for milk protein ..."
"%"
0 1.41 0
"Constants (intercepts), regression coefficients and reference values for fat content
in individual classes"
"MU/% fat"
0 2.261 0
"Constants (intercepts), regression coefficients and reference values for protein con-
```

[21] see Paragraph 4.1.1.14 on page 50

[22] see footnote 20 on the preceding page

```
tent in individual classes"
"MU/% protein"
0.45
"Standard deviation for milk fat content"
"%"
0.213
"Standard deviation for milk protein content"
"%"
...
```

4.3.11.4 Example 4 for INPUT28.TXT for filling in Part B of the input file

This is a third example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price[23] (variable *milkprice*) takes one of the following values: 3, 4 or 5.

There is a basic milk price[24] paid for milk with given fat (4.2%) and protein (3.4%) content. For fat content greater than 4.2%, 1.155 MU is paid for each additional per cent, for fat content lower than 4.2%, the same value is subtracted from the base price for each per cent. For protein content greater than 3.4%, 1.575 MU is paid for each additional per cent, for protein content lower than 3.4%, the same value is subtracted from the base price for each per cent. There is again only one class for regression. The regression equation for fat content is:

$$y = 0 + 1.155(x - 4.2) = 1.155(x - 4.2) \tag{4.5}$$

so that $b_0 = 0$, $b_1 = 1.155$ and $x_r = 4.2$. For protein content we get

$$y = 0 + 1.575(x - 3.4) = 1.575(x - 3.4) \tag{4.6}$$

that means $b_0 = 0$, $b_1 = 1.575$ and $x_r = 3.4$.
The relevant part of the input file looks therefore as follows:

```
/* ...  */
...
/* ...  */
0
"Parameter for the dependence of the milk price on the milk fat content ..."
" "
0
"Threshold values for milk fat ..."
"%"
0
"Parameter for the dependence of the milk price on the milk protein content ..."
" "
0
"Threshold values for milk protein ..."
"%"
0 1.155 4.2
"Constants (intercepts), regression coefficients and reference values for fat content
in individual classes"
"MU/% fat"
0 1.575 3.4
"Constants (intercepts), regression coefficients and reference values for protein con-
tent in individual classes"
"MU/% protein"
0.45
"Standard deviation for milk fat content"
"%"
0.213
"Standard deviation for milk protein content"
"%"
...
```

[23] see Paragraph 4.1.1.14 on page 50
[24] see footnote 20 on page 86

4.3.11.5 Example 5 for INPUT28.TXT for filling in Part B of the input file

This is the last example for modelling the dependence of the milk price on the fat and/or protein content. It is relevant if the option for the calculation of the milk price[25] (variable *milkprice*) takes one of the following values: 3, 4 or 5.

In this example, there is a penalty of 0.1 MU per per cent of fat content below 3.8%. If fat content is between 3.8 and 4.5%, a bonus of 0.1 MU per percent of fat is paid. For fat content greater than 4.5% no bonus is paid (milk price with fat content above 4.5% is the same as the price for milk with 4.5% fat). This system may be described by one threshold value (4.5%). The payment below and above 3.8% fat (until 4.5% fat) can be described by the following equation:

$$y = 0 + 0.1(x - 3.8) = 0.1(x - 3.8) \tag{4.7}$$

so that $b_0 = 0$, $b_1 = 0.1$ and $x_r = 3.8$. From this equation we calculate for $x = 4.5$ a value of $y = 0.1(4.5 - 3.8) = 0.07$. Therefore, for a fat content greater than the threshold value 4.5% we get the second regression equation as

$$y = 0.07 + 0(x - 0) = 0.07 \tag{4.8}$$

That means that $b_0 = 0.07$, $b_1 = 0$ and $x_r = 0$.

For milk with a protein content of 3.2%, the basic milk price is paid.

> Comment: The basic milk price is the first input parameter in INPUT28.TXT (*milkprice* = 3 or 5) or is calculated from the prices of the individual milk quality classes (*milkprice* = 4).

For each per cent of protein above this value, additional 0.78 MU are paid; for each per cent of protein below this value, the same penalty is subtracted. Therefore, for protein no threshold value is given and the regression is over the whole interval of protein content:

$$y = 0 + 0.78(x - 3.2) = 0.78(x - 3.2) \tag{4.9}$$

so that $b_0 = 0$, $b_1 = 0.78$ and $x_r = 3.2$.

The appropriate part of input file INPUT28.TXT is then:

```
/* ...  */
...
/* ...  */
1
"Parameter for the dependence of the milk price on the milk fat content ..."
" "
4.5
"Threshold values for milk fat ..."
"%"
0
"Parameter for the dependence of the milk price on the milk protein content ..."
" "
0
"Threshold values for milk protein ..."
"%"
0 0.1 3.8
0.07 0 0
"Constants (intercepts), regression coefficients and reference values for fat content
in individual classes"
"MU/% fat"
0 0.78 3.2
"Constants (intercepts), regression coefficients and reference values for protein con-
tent in individual classes"
```

[25] see footnote 23

```
"MU/% protein"
0.45
"Standard deviation for milk fat content"
"%"
0.213
"Standard deviation for milk protein content"
"%"
...
```

4.3.11.6 Example 6 for INPUT28.TXT for filling in part C of the input file

This part of the input file is read if the option for the calculation of the milk price[26] (variable *milkprice*) takes one of the following values: 2, 4 or 5. The text of the input file should be sufficiently self-explanatory. Just a short comment. If the number of classes for somatic cell count is 4 then there are 4-1=3 boundaries between the classes. Therefore, the upper limits are given only for classes 1 to 3.

```
/* The following part of the input file until the next comment is read only if the
option for the calculation of the milk price takes one of the following values:  2, 4
or 5.  For details see the manual.  */
4.51765
"Mean of somatic cell score in the dairy cow population"
" "
0.23529
"Phenotypic standard deviation of somatic cell score in the dairy cow population"
" "
4
"Number of milk quality classes according to somatic cell content"
" "
250000 400000 600000
"Upper limits for somatic cell count in the individual milk quality classes (the 1st
class being the best)"
"Number of somatic cells/ml milk"
```

4.3.11.7 Example 7 for INPUT28.TXT for filling in part D of the input file

This part of the input file is read if the option for the calculation of the milk price[27] (variable *milkprice*) is 2 or 4. The number of values given is identical to the number of classes for somatic cell count defined in Part C of the input file. For four classes, Part D looks like that:

```
/* The vector of basic prices is read only if the option for the calculation of the
milk price takes one of the following values:  2 or 4.  For details see the manual.  */
8.20 8.10 2.30 1.00
"Vector of basic prices per kg milk in quality class i (i=0 to nSCC-1 where nSCC is
the number of milk quality classes according to somatic cell count)"
"MU/kg"
```

4.3.11.8 Example 8 for INPUT28.TXT for filling in part E of the input file

This part of the input file is read if the option for the calculation of the milk price[28] (variable *milkprice*) is 5. In the example, four milk quality classes on the basis of somatic cell count are assumed. The first class is always assumed to be the best. Assume that the basic milk price was read and corrected for fat and/or protein content. This value be 8.15 MU[29]/kg. In the first class, it is assumed that 0.05 MU/kg were added to this price. That means, the multiplicative coefficient is 1

[26] see Paragraph 4.1.1.14 on page 50
[27] see footnote 26
[28] see footnote 26
[29] monetary units

and the additive correction factor is 0.05. The milk price in this class is then: $1 \cdot 8.15 + 0.05 = 8.20$ MU/kg. In the second class, no correction is assumed, i.e. the multiplicative correction factor is 1 and the additive correction factor is 0. The final milk price is therefore calculated as $1 \cdot 8.15 + 0 = 8.15$ MU/kg. In the third and the forth classes, 30% and 10%, respectively, of the original price are payed. The multiplicative correction factors are therefore 0.3 and 0.1, respectively. The milk price in these classes is $0.3 \cdot 8.15 + 0 = 2.45$ MU/kg or $0.1 \cdot 8.15 + 0 = 0.82$ MU/kg, respectively. The part of the input file looks then as follows:

```
/* The correction factors are read only if the option for the calculation of the milk
price takes the value 5.  For details see the manual.  */
1.0   0.05
1.0   0.0
0.3   0.0
0.1   0.0
"Multiplicative and additive correction factors for milk quality classes on the basis
of SCC"
"-   MU/kg"
```

See also Paragraph 2.5.1.2.5 on page 27 for further examples.

4.3.12 Input file INPUT29.TXT

This file contains input parameters for the calculation of cost due to clinical mastitis (CM) in the cow herd. It is necessary only if the economic weight for clinical mastitis is to be calculated (option 1 for 'Data for mastitis incidence' in parameter file PARAD.TXT - see Section 4.1.3 on page 51). The parameters in the file are:

- Cost for drugs per average CM case
- Veterinarian's time spend per average CM case
- Average charge for veterinary service
- Herdsman's time dealing with an average CM case (treatment, separate milking etc.)
- Value of herdsman's time
- Depreciation cost for a separate milking machine per year and per ill cow
- Price per dose of drug for drying cows
- Proportion of cows that are dried with antibiotics per calving interval
- Vector of incidence rate of CM (number of CM cases) per cow-year at risk in lactations 1 to LL

4.3.13 Input file INPUT30.TXT

This file contains the daily mastitis incidence (number of cows having mastitis divided by the total number of cows in the herd for the given day) for days 1 to 400 of 1st, 2nd and 3rd and subsequent lactations. The first number in each row is the day of lactation, the following three numbers are the mastitits incidence for the 1st, 2nd and 3rd and subsequent lactations, respectively. The file is necessary only if the economic weight for clinical mastitis is to be calculated (option 1 for 'Data for mastitis incidence' in parameter file PARAD.TXT - see Section 4.1.3 on page 51).

4.3.14 Input file FROM1_3.TXT

This file is produced from the program EWBC (see Section 5.1.3 on page 94). It is necessary if there is a connection between the dairy system and a production system of type 3. In this case, Production System 3 has to be calculated in the program EWBC before running the program EWDC.

4.4 TEXT_OUT.TXT and TEXTD_OUT.TXT: files containing text for writing results

These files contain texts which are used for printing the results. They contain headings of sections of the results files, comments and names of variables the values of which are printed in the results files. For editing the files read carefully the remarks at the beginning of Section 4 on page 46. The file TEXT_OUT.TXT is needed for Production Systems 1 to 3 (program EWBC) and the file TEXTD_OUT.TXT is necessary for Production System 4 (program EWDC).

Chapter 5

Program output

5.1 Output files for Production Systems 1 to 3 (program EWBC)

5.1.1 The results file

The name of the file the results are written to is determined by the user when starting the program. The first part of the file contains the following information:

- Version of the program, copyright and contact to the authors
- System variables (read from PARA.TXT, see Section 4.1.2)
- Input parameters read from the individual input files

The second part contains the following results:

- Structure of the cow herd in the stationary state
- Reproduction characteristics of the herd
- Growth of cows in reproductive cycles 1 to 3
- Characteristics of progeny born in the herd
- Nutrition cost
- Further cost components and total costs per animal in each category
- Cost for dystocia
- Revenues
- Number of discounted expressions (covering only one generation of offspring where heifers are included till calving) for revenues and costs of all categories of cattle per cow and year
- Profit
- Marginal economic values for all traits
- Economic weights for direct and maternal components for the selection group chosen

Remark. It may happen that some values are printed which have no relevance for the given calculation. These preliminary results are automatically calculated from the default values in the input files. They are ignored in the calculation of total costs, revenues, profit and economic values. For example, feed costs for castrates may be printed even if there are no castrates. When calculating total costs, these costs are multiplied by the proportion of animals in the given category. So, if there are no castrates, this product will be zero. Therefore, just ignore all quantities which have no relevance to your calculation.

5.1.2 File CHECK

This file is of importance mainly for people who are interested in a further development of the program. The file lists the values of all variables (except some index variables and temporary variables) used in the program. The file can be useful for finding bugs in the program. A good way of checking the program was to calculate two versions of economic values - one for a change of 0.5% down and upwards in the trait (variables ew[i]) and a second one for a change of 1% to both sides in the trait (variables ew0[i]). The difference between these two numbers expressed in per cent (ewdiff[i]) should be reasonably low, generally less than one per cent.

5.1.3 File FROM1_3.TXT

This file is needed for Production System 4 (program EWDC) in several cases. It contains the following information:

- A short comment.
- The number of the production system (see Section 4.1.1.1).
- The number of reproductive cycles (LL in program EWBC, read as $L3$ in program EWDC)
- Vector **l3** (LL elements: cows calving in reproductive cycles 1 to LL expressed as proportion of cows entering any reproductive cycle)
- Vector **ew** (economic values, 29 elements, see numbering of traits in the Appendix on page 98). The values are read in as ew[i][2] with $i = 1, ..., 29$.

5.2 Output files for Production System 4 (program EWDC)

5.2.1 The results file

The name of the file the results are written to is determined by the user when starting the program. The first part of the file contains the following information:

- Version of the program, copyright and contact to the authors
- System variables (read from PARAD.TXT, see Section 4.1.3)
- Input parameters read from the individual input files

The second part contains the following results:

- Structure of the cow herd in the stationary state
- Reproduction characteristics of the herd

- Growth of cows in reproductive cycles 1 to 3
- Characteristics of progeny born in the herd
- Nutrition cost
- Cost per animal in each category
- Cost for dystocia
- Revenues
- Number of discounted expressions for revenues and costs for all categories of cattle per SFU (covering only one generation of progeny, where heifers are included till calving)
- Profit
- Marginal economic values
- Economic weights for direct and maternal components for the selection group chosen

Remark. See remark at the end of Section 5.1.1 on page 93.

5.2.2 File CHECKD

This file is of importance mainly for people who are interested in a further development of the program. The file lists the values of all variables (except some index variables and temporary variables) used in the program.

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Appendix A

Lists of traits and of variables in EWBC and EWDC

A.1 Some useful comments

Indices are used in different manners for distinct arrays. The index variable referring to the reproductive cycle is always identical with the number of the reproductive cycle decremented by one; reproductive cycles 1 to LL are represented by the values 0 to $LL-1$ of the appropriate index variable. The same principle is applied to most cases when the dimension is less or equal to 10. In arrays with higher dimension, the value of the index variable in the program is, as a rule, identical to its real value; the index used for the category of animals in the program, for example, is always identical with the numbers given in the manual in Section 2.2.2. When the index for the category of animals is calculated from the number of the reproductive cycle (symbol r is used in these cases) the real number of the reproductive cycle as given in Section 2.2.1 is to be inserted.

Proportions are usually understood as fractions. Deviations from this general principle are specified in the description of the variable (in some cases, proportions are given as percentage).

For finding possible bugs in the program, the economic values are calculated twice. The values calculated as described in Section 2.7 and printed to the results file will be found in the vector $ew[i]$ for Program EWBC and in the vector $ew[i][j]$ for Program EWDC. For each trait a second value is calculated by shifting the value of the trait by twice the value it was shifted for $ew[i]$ or $ew[i][j]$, respectively. These latter values will be found in the vector $ew0[i]$ or $ew0[i][j]$, respectively. If the program works well, the difference between these two values given in the vector $ewdiff[i]$ or $ewdiff[i][j]$, respectively, in per cent should be small, to our experience mostly 1% or less. Nevertheless, in some traits where the profit depends strongly nonlinearly on the trait value, the difference may be somewhat greater (2 to 3%). If you will observe greater values for these differences (all these values are printed in the files CHECK or CHECKD - see Sections 5.1.2 or 5.2.2, respectively), something is probably going wrong. Inform please the authors of the program in this case.

A.2 Numbering of traits

The following numbering of traits is used in the program:

1 Average score for calving performance (male and female calves together)

2	Losses of calves at calving
3	Losses of calves from 48 hours till weaning or till the end of the rearing period
4	Mature weight of cows
5	Birth weight of calves
6	Program EWBC: Average daily gain of calves from birth to 1st weighing
7	Program EWBC: Average daily gain of calves from 1st to 2nd weighing
8	Program EWBC: Average daily gain of calves from 2nd to 3rd weighing
9	Average daily gain in fattening period to constant slaughter weight
10	Dressing percentage
11	Cow losses
12	Conception rate of heifers
13	Conception rate of cows
14	Mean class of fleshiness for cows
15	Mean class of fleshiness for bulls
16	Mean class of fleshiness for heifers
17	Mean class of fleshiness for castrates
18	Mean class of fleshiness for all categories together
19	Mean class of fat covering for cows
20	Mean class of fat covering for bulls
21	Mean class of fat covering for heifers
22	Mean class of fat covering for castrates
23	Mean class of fat covering for all categories together
24	Average score for calving performance (female calves)
25	Average score for calving performance (male calves)
26	Program EWBC: Weight of calves at 1st weighing
27	Program EWBC: Weight of calves at 2nd weighing
28	Program EWBC: Weight of calves at 3rd weighing
29	Average lifetime of cows
30	Program EWDC: Average daily gain from birth till the end of the rearing period
31	Program EWDC: 305d milk production
32	Program EWDC: Fat percentage
33	Program EWDC: 305d fat yield (kg)

34 Program EWDC: Protein percentage

35 Program EWDC: 305d protein yield (kg)

36 Program EWDC: Somatic cell score

37 Program EWDC: Mastitis incidence

A.3 List of variables

a Temporary variable

a1 Program EWBC: Temporary variable (e.g. convergence criterion for iteration). Program EWDC: Parameter a in the lactation curve for the 1st lactation[1]

a2 Program EWBC: Parameter a in the lactation curve (see equation (2.4) in Section 2.3) for two year old cows. Program EWDC: Parameter a in the lactation curve for the 2nd and higher lactations[2]

a3 Program EWBC: Parameter a in the lactation curve for three year old cows[3]. Program EWDC: Temporary variable

a4 Program EWBC: Parameter a in the lactation curve for four year old cows[4]

a9 Temporary variable

aa1 Temporary variable

aa2 Temporary variable

aa3 Temporary variable

aa4 Temporary variable

aa5 Temporary variable

aa6 Temporary variable

aa11 Temporary variable

ab[i] Probability of abortion for cows conceived in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

ACD Program EWBC: Maximal number of age classes for dams

acd Number of age classes for dams

ACDC Program EWDC: Maximal number of age classes for cross-bred dams

acdc Program EWDC: Number of age classes for cross-bred dams (Calculated as: Number of reproductive cycles in System 3 + age at calving in years - 1)

ACDD Program EWDC: Maximal number of age classes for dairy dams

[1] See Section 2.3 for the lactation curves and for the derivation of their parameters
[2] see footnote 1
[3] see footnote 1
[4] see footnote 1

acdd	Program EWDC: Number of age classes for dairy dams ($LL-1+$ age at calving in years)
ACM	Maximal dimension of the matrix for gene flow
acm	Dimension of matrix PM (transition matrix for gene-flow)
ACS	Program EWBC: Maximal number of age classes for sires
acs	Number of age classes for sires
ACSB	Program EWDC: Maximal number of age classes for beef sires
acsb	Program EWDC: Number of age classes for beef sires
ACSD	Program EWDC: Maximal number of age classes for dairy sires
acsd	Program EWDC: Number of age classes for dairy sires
adg[i]	Average daily gain of category i (Program EWBC: $i = 1, ..., CC + 10$, Program EWDC: $i = 1, ..., CT$)
adg10	Daily gain of bulls from the end of the rearing period of calves till selling
adg1cow	Average daily gain of cows in the 1st reproductive cycle
adg2cow	Average daily gain of cows in the 2nd reproductive cycle
adgbbt	Daily gain of bulls in test
adgcf[i]	Daily gain of female calves in the rearing period ($i = 0$ for pure-bred animals, $i = 1$ for cross-bred animals)
adgcm[i]	Daily gain of male calves in the rearing period ($i = 0$ for pure-bred animals, $i = 1$ for cross-bred animals)
adgcon1f	Average daily gain of females from birth to the first control weighing
adgcon1m	Average daily gain of males from birth to the first control weighing
adgcon2f	Average daily gain of females from first to the second control weighing
adgcon2m	Average daily gain of males from first to the second control weighing
adgcon3f	Average daily gain of females from second to the third control weighing
adgcon3m	Average daily gain of males from second to the third control weighing
adgfrep	Average daily gain (without foetus) from purchase of a breeding heifer to calving
adgh1s	Daily gain of replacement heifers in the 1st summer season after their weaning
adgh2s	Daily gain of replacement heifers in the 2nd summer season after their weaning
adgh2w	Daily gain of replacement heifers in the 2nd winter season after their weaning
adgh3s	Daily gain of replacement heifers in the 3rd summer season after their weaning

adgh3w Daily gain of replacement heifers in the 3rd winter season after their weaning

adgh4w Daily gain of replacement heifers in the 4th winter season after their weaning

adghcal Average daily gain of heifers from weaning to the 1st calving (without gain for foetus - average of heifers conceived in all 3 mating periods after weaning)

adghmc[i] Daily gain of replacement heifers from the 1st mating to calving (without foetus) ($i = 0$ for pure-bred animals, $i = 1$ for cross-bred animals)

adghm[i] Daily gain of replacement heifers from the end of rearing period to the 1st mating ($i = 0$ for pure-bred animals, $i = 1$ for cross-bred animals)

adgs Average daily gain in the summer period after weaning for category $CC + 1$

adgs0[i] Average daily gain in the "zeroeth" summer period[5] after weaning for category i ($i = CC + 1, \ldots, CC + 10$).

adgs1[i] Average daily gain in the 1st summer period after weaning for category i ($i = CC + 2, CC + 9$)

adgs2[i] Average daily gain in the 2nd summer period after weaning for category i ($i = CC + 2, CC + 3$)

adgs3[i] Average daily gain in the 3rd summer period after weaning for category i ($i = CC + 2, CC + 4$)

adgst Average daily gain from weaning to the start of the bull test in category 10

adgtm Average daily gain of bulls from the test end to reaching mature weight

adgw[i] Average daily gain in the winter period after weaning for category i ($i = 18, CC + 1$)

adgw1[i] Average daily gain in the 1st winter period after weaning for category i ($i = CC + 2, CC + 5$)

adgw2[i] Average daily gain in the 2nd winter period after weaning for category i ($i = CC + 2, CC + 4, CC + 8$)

adgw3[i] Average daily gain in the 3rd winter period after weaning for category i ($i = CC + 3, CC + 5$)

adgw4 Average daily gain in the 4th winter period after weaning for category $CC + 6$

adgwsc Program EWBC: Daily gain of castrates in intensive fattening

adgwsc[i] Program EWDC: Daily gain of pure-bred ($i = 0$) and cross-bred ($i = 1$) castrates in intensive fattening

adgwsf Program EWBC: Daily gain of heifers in intensive fattening

adgwsf[i] Program EWDC: Daily gain of pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers in intensive fattening

[5] This period occurs only if calves are weaned before the end of the pasture period.

adgwsm	Program EWBC: Daily gain of bulls in intensive fattening
adgwsm[i]	Program EWDC: Daily gain of pure-bred ($i = 0$) and cross-bred ($i = 1$) bulls in intensive fattening
adgwt	Average daily gain of bulls in test (category 10)
age[i]	Program EWDC: Age of animals in category i ($i = 1, \ldots, CT$)
agebbcull	Age of breeding bulls at culling
agebbm	Age of breeding bulls when reaching mature body weight
agebbse	Average age of performance-tested bulls at selling to the herd or insemination stations
agebbse	Age of breeding bulls at purchase for the herd
agebbst	Average age of breeding bulls at the begin of the performance test
agebbt	Average age of breeding bulls at the end of the performance test
agec1[i]	Age of calves at the end of the first feeding period during rearing ($i = 0$ for pure-bred animals, $i = 1$ for cross-bred animals)
agecal	Age of cows at first calving
agecwsc	Program EWBC: Average age of castrates culled in the fattening period before reaching slaughter weight
agecwsc[i]	Program EWDC: Average age of of pure-bred ($i = 0$) and cross-bred ($i = 1$) castrates culled in the fattening period before reaching slaughter weight
agecwsf	Program EWBC: Average age of heifers culled in the fattening period before reaching slaughter weight
agecwsf[i]	Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers culled in the fattening period before reaching slaughter weight
agecwsm	Program EWBC: Average age of bulls culled in the fattening period before reaching slaughter weight
agecwsm[i]	Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) bulls culled in the fattening period before reaching slaughter weight
agedcw	Program EWBC: Average age of calves died from 2 days of age to weaning
agedcw[i]	Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) female calves died from 2 days of age to the end of the rearing period
agedmh	Program EWBC: Average age of breeding heifers died from weaning to entering the herd
agedmh[i]	Program EWDC: Average age of breeding pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers died from the end of the rearing period to entering the herd
agedwsc	Program EWBC: Average age of castrates died in the fattening period

agedwsc[i] Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) castrates died in the fattening period

agedwsf Program EWBC: Average age of heifers died in the fattening period

agedwsf[i] Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers died in the fattening period

agedwsm Program EWBC: Average age of bulls died in the fattening period

agedwsm[i] Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) bulls died in the fattening period

agefrep Age of female for replacement at purchase

ageh1cal Program EWBC: Average age at calving for heifers conceived in the 1st mating period after weaning

ageh1cal[0] Program EWDC: Average age of pure-bred heifers at calving

ageh2cal Average age at calving for heifers conceived in their 2nd mating period after weaning

ageh3cal Average age at calving for heifers conceived in their 3rd mating period after weaning

agehcmat Average age of heifers culled after the 1st, 2nd and 3rd mating periods after weaning because of no pregnancy

agehcmat1 Program EWBC: Average age of heifers culled after their 1st mating period after weaning because of no pregnancy

agehcmat1[0] Program EWDC: Average age of pure-bred heifers culled after their mating period because of no pregnancy

agehcmat2 Average age of heifers culled after their 2nd mating period after weaning because of no pregnancy

agehcmat3 Average age of heifers culled after their 3rd mating period after weaning because of no pregnancy

agehmat Average age of heifers at mating (weighted average from all 3 mating periods)

agehmat1 Program EWBC: Average age at mating for heifers mated in their 1st mating period after weaning.

agehmat1[i] Program EWDC: Average age of heifers at their 1st mating (1st insemination) ($i = 0$ for pure-bred heifers, $i = 1$ for cross-bred heifers)

agehmat2 Average age at mating for heifers mated in their 2nd mating period after weaning

agehmat3 Average age at mating for heifers mated in their 3rd mating period after weaning

agesc Program EWBC: Average age of castrates at the end of the fattening period

agesc[i] Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) castrates at the end of the fattening period

agesf	Program EWBC: Average age of heifers at the end of the fattening period
agesf[i]	Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers at the end of the fattening period
agesm	Program EWBC: Average age of bulls at the end of the fattening period
agesm[i]	Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) bulls at the end of the fattening period
agew	Program EWBC: Average age of calves at weaning
agew[i]	Program EWDC: Average age of pure-bred ($i = 0$) and cross-bred ($i = 1$) calves at the end of rearing period
aic	Proportion of insemination in cows
aih	Heifers mated in their 1st oestrus within the given mating period as proportion of all mated heifers in this period
aihc	Heifers pregnant in their 1st oestrus within the given mating period as proportion of all heifers which entered this mating period
am	Parameter a in the lactation curve for cows older than four years[6]
anphse	Program EWBC: Average age of non-pregnant breeding heifers at selling
anphse1	Program EWBC: Average age of breeding heifers sold before the first mating period after their weaning
anphse2	Program EWBC: Average age of non-pregnant breeding heifers sold between the first and second mating period after their weaning
aphse	Program EWBC: Average age of pregnant breeding heifers at selling
aphse1	Program EWBC: Average age of pregnant breeding heifers sold after the first mating period after their weaning
aphse1	Program EWBC: Average age of pregnant breeding heifers sold after the second mating period after their weaning
avecalc	Average number of cross-bred calvings in the herd per cow and reproductive cycle
avelifecc	Average productive life time of cows (in numbers of calvings)
avelifecl	Average productive lifetime of cows in number of lactations (not taking into account that some cows had shorter lactations due to culling or death during the reproductive cycle)
avelifecy	Average productive life time of cows (in years)
avh	Temporary variable used in the calculation of economic values of several traits
avl	Temporary variable used in the calculation of economic values of several traits

[6] See Section 2.3 for the lactation curves and for the derivation of their parameters

b1 Program EWDC: Parameter b in the lactation curve for the 1st lactation[7]

b2 Program EWBC: Parameter b in the lactation curve for two year old cows. Program EWDC: Parameter b in the lactation curve for the 2nd lactation[8]

b3 Program EWBC: Parameter b in the lactation curve for three year old cows. Program EWDC: Parameter b in the lactation curve for the 3rd and higher lactations[9]

b4 Program EWBC: Parameter b in the lactation curve for four year old cows[10]

b9 Temporary variable

bm Program EWBC: Parameter b in the lactation curve for cows older than 4 years[11]

bw[i] Program EWBC: Average birth weight of calves (female calves ($i = 8$), male calves ($i = 9$), averaged over sexes ($i = 3$)). Program EWDC: Average birth weight of calves ($i = 3, 8, 9, 10, CC + 3, CC + 8, CC + 9$)

bwf Program EWBC: Weight of female calves at birth

bwf[i] Program EWDC: Weight of pure-bred ($i = 0$) and cross-bred ($i = 1$) female calves at birth

bwm Program EWBC: Weight of male calves at birth

bwm[i] Program EWDC: Weight of pure-bred ($i = 0$) and cross-bred ($i = 1$) male calves at birth

C Program EWBC: Maximal number of categories of animals + 1, Program EWDC: Total number of categories of animals + 1

C1 Program EWDC: Total number of pure-bred categories of animals + 1

c1 Program EWDC: Parameter c in the lactation curve for the 1st lactation[12]

c2 Program EWBC: Parameter c in the lactation curve for two year old cows. Program EWDC: Parameter c in the lactation curve for the 2nd lactation[13]

c3 Program EWBC: Parameter c in the lactation curve for three year old cows. Program EWDC: Parameter c in the lactation curve for the 3rd and higher lactations[14]

c4 Program EWBC: Parameter c in the lactation curve for four year old cows[15]

[7] see footnote 6
[8] see footnote 6
[9] see footnote 6
[10] see footnote 6
[11] see footnote 6
[12] see footnote 6
[13] see footnote 6
[14] see footnote 6
[15] see footnote 6

c9	Temporary variable
cal[j][i]	Number of pure-bred ($j = 0$) and cross-bred ($j = 1$) calvings per cow and reproductive cycle $i + 1$ ($i = 0, ...LL - 1$)
calfloss	Total calf losses at calving (abort, stillbirth, death till 48 hours after calving)
calfloss[i]	Total calf losses at calving (abort, stillbirth, death till 48 hours after calving) for pure-bred ($i = 0$) and cross-bred ($i = 1$) calves
cb	Program EWDC: The parameter indicates if crossbreeding is used ($cb = 1$) or not ($cb = 0$)
CC	Program EWBC: Number of categories of animals, $CC = 6(LL - 1) + 4 + 24 = TT + 24$. Program EWDC: Number of categories of animals if there is no crossbreeding
cculcm[i]	Cows culled from calving to mating for health problems other than dystocia in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) as proportion of cows entering the cycle
cculmc[i]	Cows culled from mating to calving for health problems other than dystocia in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) as proportion of cows entering the cycle
ciav	Average calving interval in the herd calculated only for the cows that entered the next reproductive cycle
ci[i]	Calving interval for reproductive cycle $i + 1$ ($i = 0, ...LL - 1$)
clcm[i]	Cow losses from calving to mating for reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)
clmc[i]	Cow losses from mating to next calving for reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)
cm	Program EWBC: Parameter c in the lactation curve for cows older than 4 years[16]
cmat[i]	Cows entering the mating period in reproductive cycle $i + 1$ expressed as proportion of the number of cows at the beginning of this cycle ($i = 0, ..., LL - 1$)
cmd	Culling rate of cows after dystocia (assumed to be equal in all reproductive cycles)
con_1	Age of calves at first weighing
con_2	Age of calves at second weighing
con_3	Age of calves at third weighing
conh[i]	Heifers conceived after the ith insemination ($i = 0, ..., inmaxh$) as proportion of firstly inseminated heifers
conh1	Heifers conceived in the 1st mating period after their weaning expressed as proportion of all heifers which entered the 1st mating period

[16] See Section 2.3 for the lactation curves and for the derivation of their parameters

conh2 Heifers conceived in the 2nd mating period after their weaning expressed as proportion of all heifers which entered the 1st mating period

conh3 Heifers conceived in the 3rd mating period after their weaning expressed as proportion of all heifers which entered the 1st mating period

cost[i] Vector of total cost for category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costbb Total cost for a breeding bull for natural mating in the herd from purchase to slaughter

costc Total costs per cow and year (averaged over all cow categories)

costcowy Average cost per cow and year in the cow-calf pasture system (including cost for replacement and dead calves without additional feeding costs for calves weaned) corrected for revenues from culled cows and heifers

costcw Average cost in the cow-calf pasture system per weaned calf without additional feeding cost for calf

costcwf Average cost in the cow-calf pasture system including additional feeding cost per weaned female calf

costcwfkg Average cost in the cow-calf pasture system per kg life weight of weaned female calves

costcwm Average cost in the cow-calf pasture system including additional feeding cost per weaned male calf

costcwmkg Average cost in the cow-calf pasture system per kg life weight of weaned male calves

costd[i] Cost for removing and rendering a dead mature animal of category i

costdc Cost for removing and rendering a dead cow

costdcf[i] Program EWDC: Average cost for removing and rendering of a dead pure-bred ($i = 0$) or cross-bred ($i = 1$) calf in the rearing period

costdf Program EWBC: Cost for removing and rendering of one young animal (in fattening or rearing)

costdf[i] Program EWDC: Average cost for removing and rendering of a dead young pure-bred ($i = 0$) or cross-bred ($i = 1$) animal (replacement heifer or animal in fattening)

costdrug Cost for drugs per average CM case

costdys Average cost of dystocia per cow and year

costdysc Average cost for dystocia per calving

costf[i] Total cost for feeding (including water and minerals) per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costfas[i] Cost for feeding after extensive fattening on pasture if the required slaughter weight was not reached at the end of this fattening period, per animal of category i ($i = 5, 6, 12, 13, 15, 16, 17$)

costfatb Average cost in fattening per slaughtered bull reaching the given slaughter weight (including costs for losses and culling for health, without costs for purchased weaned male calf for fattening)

costfatbkg Average cost in fattening per kg carcass weight of bulls (without costs for purchased weaned male calf for fattening)

costfatc Average cost in fattening per slaughtered castrate reaching the given slaughter weight (including costs for losses and culling for health, without costs for purchased male calf for fattening)

costfatckg Average cost in fattening per kg carcass weight of castrates (without costs for purchased weaned male calf for fattening)

costfath Average cost in fattening per slaughtered heifer reaching the given slaughter weight (including costs for losses and culling for health, without costs for purchased female calf for fattening)

costfathkg Average cost in fattening per kg carcass weight of heifers (without costs for purchased weaned female calf for fattening)

costfbb Total cost for feeding per breeding bull from purchase to slaughter

costfbbs Cost for summer feeding per breeding bull from purchase to slaughter

costfbbw Cost for winter feeding per breeding bull from purchase to slaughter

costfc Cost for feeding (including water and minerals) per cow and year (averaged over all cow categories)

costff[i] Cost for feeding in intensive fattening per animal of category i ($i = 4, 5, 6, 12, 13, 14, 15, 16, 17$)

costfix[i] Fixed cost per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costfixc Fixed cost per cow and year (averaged over all cow categories)

costfixwf[i] Fixed cost in the rearing period per female calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costfixwm[i] Fixed cost in the rearing period per male calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costfs[i] Cost for summer feeding per animal of category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)

costft Cost for feeding per breeding bull in the performance test

costftb Cost for feeding per breeding bull before the performance test

costftse Cost for feeding per breeding bull from the end of the performance test to selling

costfw[i] Cost for winter feeding per animal of category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)

costfwf[i] Cost for nutrition (food and water) in the rearing period per female calve ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costfwm[i] Cost for nutrition (food and water) in the rearing period per male calve ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costh[i] Cost for housing (difference of cost for straw and revenues for dung) per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costhbb Cost for housing (difference of cost for straw and revenues for dung) per breeding bull in the herd from purchase to slaughter

costhc Cost for housing (difference of cost for straw and revenues for dung) per cow and year (averaged over all cow categories)

costhnpr Average cost for breeding heifers sold to other systems before mating (including proportional cost per cow)

costhnprkg Average cost per kg live weight of breeding heifers sold to other systems before mating (including proportional cost per cow)

costhpr Average cost for pregnant breeding heifers sold to other systems (including proportional cost per cow)

costhprkg Average cost per kg live weight of pregnant breeding heifers sold to other systems (including proportional cost per cow)

costhwf[i] Cost for housing (difference of cost for straw and revenues for dung) in the rearing period per female calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costhwm[i] Cost for housing (difference of cost for straw and revenues for dung) in the rearing period per male calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costi Program EWBC: Cost for breeding bulls (natural mating) per female and reproductive cycle

costi[i] Program EWDC: Cost for insemination per category i

costimc Cost for insemination and natural mating per cow and reproductive cycle

costimh Cost for insemination and natural mating per heifer and mating period

costlab Cost per stock-man hour (needed for dystocia cost)

costlabm Labour cost for herdsman's time dealing with CM per cow and year

costm[i] Cost for minerals per animal of category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)

costmach Depreciation cost for a separate milking machine per year and per cow ill with clinical mastitis

costmbb Cost for minerals per breeding bull from purchase to slaughter

costmilkv[i] Part of variable costs for milk for category i ($i = NCP, ..., CC$)

costo[i] Other cost in category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costoc Other cost (breeding cost, cost for removing and rendering of dead cows) per cow and year (averaged over all cow categories)

costom other costs connected with clinical mastitis per cow and year

costv[i] Cost for veterinary treatment per animal of category i ($i = 1, ..., CC$), in program EWDC only defined for $i = 30$.

costvbb Cost for veterinary treatment per bull in the herd per reproductive cycle

costvbbt Total veterinary cost per breeding bull in the herd from purchase to culling

costvet[i] Cost for veterinary treatment per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costvet10 Cost for veterinary treatment per bull from the end of rearing period of calves till selling

costvetc Cost for veterinary treatment per cow and year (averaged over all cow categories)

costvetm cost for drugs and veterinary service for mastitis treatment, per cow and year

costvetwf[i] Veterinary cost per female calve in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costvetwm[i] Veterinary cost per male calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costvfi Cost for veterinary treatment per animal in intensive fattening

costvfx Cost for veterinary treatment per animal in extensive fattening

costwf[i] Total cost per female calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costwm[i] Total cost per male calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costwt[i] Cost for water per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

costwtbb Cost for water per breeding bull from purchase to slaughter

costwwf[i] Cost for water per female calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

costwwm[i] Cost for water per male calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

cowb Number of cows per bull for natural mating

cowyear Number of stable places needed per cow and reproductive cycle

cp[i] Total number of pregnant cows (weighted for cows with and without dystocia) in the mating period of reproductive cycle $i+1$ ($i = 0, ..., LL-2$) as proportion of cows calved in this cycle

cp2nm[i] Probability that a cow (weighted average for cows with and without dystocia) not pregnant in the 1st oestrus will be pregnant in the 2nd oestrus within the mating period of reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

cp3nm[i] Probability that a cow (weighted average for cows with and without dystocia) not pregnant in the 2nd oestrus will be pregnant in the 3rd oestrus within the mating period of reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

cpin[i] Program EWBC: Probability that a calved cow (weighted average for cows with and without dystocia) will be pregnant in the 1st oestrus in the mating period of reproductive cycle $i+1$ ($i = 0, ..., LL-2$)

cpin[i][j] Program EWDC: Probability that a calved cow in cycle $i+1$ ($i = 0, ..., LL-2$) will be pregnant after insemination j ($j = 0, ..., inmax-1$) (weighted average for cows with and without dystocia)

cpindys[i][j] Cows having dystocia in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) and becoming pregnant after insemination j ($j = 0, ..., inmax-1$) as proportion of all pregnant cows in reproductive cycle $i+1$.

cpinndys[i][j] Cows without dystocia in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) becoming pregnant after insemination j ($j = 0, ..., inmax-1$) as proportion of all pregnant cows in reproductive cycle $i+1$.

cr2nmh Conception rate of heifers in the 2nd oestrus within a mating period expressed as proportion of heifers not being pregnant after the 1st oestrus in this mating period

cr3nmh Conception rate of heifers in the 3rd oestrus within a mating period expressed as proportion of heifers not being pregnant after the 2nd oestrus in this mating period

crcmp[i] Cows conceived after the mating period of reproductive cycle $i+1$ expressed as proportion of all mated cows in this cycle ($i = 0, ..., LL-2$)

crdys Average decrease in conception rate of cows caused by dystocia (average over all oestrus and reproductive cycles)

crh1mp Total conception rate of heifers in a mating period

crhmp Heifers conceived in one of the three mating periods after their weaning expressed as proportion of all heifers which entered the 1st mating period (only three subsequent mating periods are allowed for heifers after their weaning)

crinh Program EWBC: Conception rate of heifers in the 1st oestrus during the first part of the mating period expressed as proportion of heifers mated in this oestrus

crinh[i] Program EWDC: Conception rate of heifers after insemination i ($i = 0, ..., inmaxh-1$)

CT Program EWDC: Total number of animal categories ($CT = TT + 48$)

culh[i] Vector of cows involuntarily culled within reproductive cycle $i+1$ ($i = 0, ..., LL-1$) for other health problems than dystocia as proportion of cows which entered this reproductive cycle

culvol[i] Vector of cows voluntarily culled within reproductive cycle $i+1$ ($i = 0, ..., LL-1$) for low milk production as proportion of cows which entered this reproductive cycle

D Program EWDC: Maximal number of classes for calving performance

d[i] Days for which the costs per animal of category i are calculated (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

d1	Parameter d for the lactation curve for the first lactation[17]
d1w[i]	Length of the first feeding period in the rearing period of calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
d2	Parameter d for the lactation curve for the second lactation[18]
d3	Parameter d for the lactation curve for the third and higher lactations[19]
d9	Temporary variable
da	Temporary variable
dasc	Days of feeding castrates after pasture in extensive fattening to reach the required slaughter weight
dasf	Days of feeding heifers after pasture in extensive fattening to reach the required slaughter weight
davcal	Average calving date for all females (heifers and cows) calving in the herd
davcalc	Average date of calving for cows in the herd
davcalh	Average date of calving for heifers in the herd
davmat	Average date of mating for all females (heifers and cows) in the herd
davmatc	Average date of mating for cows in the herd
davmath	Average date of the 1st mating for heifers in the herd
daysc	Days from purchase of a pregnant female to calving
dayshc	Program EWBC: Number of days from the average date of mating to the date of culling of not pregnant heifers
dayshc[i]	Program EWDC: Number of days from the average date of mating to the date of culling of not pregnant pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers
dayslac[i]	Length of the whole lactation in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) (difference of the length of the calving interval and days dry)
dbb[i]	Number of days breeding bulls are kept in the herd (from purchase to culling)
dbpas	Date of beginning pasture
dc1[i]	Length of the first feeding period for a calf of category i ($i = 3, 8, 9, 10, CC+3, CC+8, CC+9, CC+10$)
dcalai	Average date of calving for females conceived in the 1st oestrus in the mating period
dcalmat	Average interval in days from date of calving to date of mating
dcalnm2	Average date of calving for females conceived in the 2st oestrus in the mating period

[17] See Section 2.3 for the lactation curves and for the derivation of their parameters
[18] see footnote 17
[19] see footnote 17

dcalnm3 Average date of calving for females conceived in the 3st oestrus in the mating period

dccf Program EWBC: Losses of castrates in the fattening period

dccf[i] Program EWDC: Losses of pure-bred ($i = 0$) and cross-bred ($i = 1$) castrates in the fattening period

dcd[i] Calves died to 48 hours expressed as proportion of calves born alive after dystocia in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dce[i] Calves died to 48 hours expressed as proportion of calves born alive after easy calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dconai Average date of conception for cows conceived in the 1st oestrus in the mating period

dconnm2 Average date of conception for cows conceived in the 2st oestrus in the mating period

dconnm3 Average date of conception for cows conceived in the 3st oestrus in the mating period

dcost[i] Length of the period for which the costs are calculated for category i ($i = 1, ..., CC$)

dcostw[i] Length of the winter period for which the costs are calculated for category i ($i = 1, ..., CC$ except categories $4, 14, 15$)

dcw Program EWBC: Losses of calves from 48 hours after calving to weaning (averaged over sexes and reproductive cycles)

dcw[i] Program EWDC: Losses of pure-bred ($i = 0$) and cross-bred ($i = 1$) calves from 48 hours after calving to the end of the rearing period (averaged over sexes and reproductive cycles)

DD Program EWDC: Number of classes for calving performance

dd Average days dry per cow

dead48[i] Probability that a calf born alive dies till 48 hours after calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dead48f[i] Program EWBC: Probability that a female calf born alive dies till 48 hours after calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dead48f[i][j] Program EWDC: Probability that a pure-bred ($i = 0$) or cross-bred ($i = 1$) female calf born alive dies till 48 hours after calving in reproductive cycle $j + 1$ ($j = 0, ..., LL - 1$)

dead48m[i] Program EWBC: Probability that a male calf born alive dies till 48 hours after calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dead48m[i][j] Program EWDC: Probability that a pure-bred ($i = 0$) or cross-bred ($i = 1$) male calf born alive dies till 48 hours after calving in reproductive cycle $j + 1$ ($j = 0, ..., LL - 1$)

deadc[i] Probability that a cow in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) will bear a dead calf

deadfc[i] Program EWBC: Probability that a cow in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) will bear a dead female calf

deadfc[i][j] Program EWDC: Probability that a cow in reproductive cycle $j+1$ ($j = 0, ..., LL-1$) will bear a dead pure-bred ($i = 0$) or cross-bred ($i = 1$) female calf

deadmc[i] Program EWBC: Probability that a cow in reproductive cycle $i+1$ ($i = 0, ..., LL-1$) will bear a dead male calf

deadmc[i][j] Program EWDC: Probability that a cow in reproductive cycle $j+1$ ($j = 0, ..., LL-1$) will bear a dead pure-bred ($i = 0$) or cross-bred ($i = 1$) male calf

deai Date of ending the first part of the mating period covering the first possibility of a female to become pregnant (1st oestrus)

deltacow In the calculation of economic weights: change in the number of cows

deltamilk In the calculation of economic weights: change in *milktot*

denm2 Date of ending the 2nd part of the mating period covering the second possibility of females to become pregnant (2nd oestrus)

denm3 Date of ending the 3rd part of the mating period (end of the mating period) covering the 3rd possibility of females to become pregnant (3rd oestrus)

depas Date of ending pasture

dfcf Program EWBC: Losses of heifers in the fattening period

dfcf[i] Program EWDC: Losses of pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers in the fattening period

dfrp Losses of heifers in the rearing period (from weaning to mating)

dgcxas Daily gain of castrates in the fattening period after extensive fattening on pasture

dgcxs Daily gain of castrates in the summer period on pasture in extensive fattening

dgcxw Daily gain of castrates in the winter period after their weaning in extensive fattening

dgfxas Daily gain of heifers in the fattening period after extensive fattening on pasture

dgfxs Daily gain of heifers in the summer period on pasture in extensive fattening

dgfxw Daily gain of heifers in the winter period after their weaning in extensive fattening

discow[i] discarded milk due to clinical mastitis per cow of category i ($i = NCP, ..., CC$)

dismilk total discarded milk due to clinical mastitis per cow and year

DL Parameter: maximal number of days in lactation ($DL = 400$)

dl[i]	Length of the lactation for cow of category i
dm	Days from purchase to reaching mature weight of breeding bulls
dmatpas	Average interval in days from average date of mating to the end of the summer season
dmcf	Program EWBC: Losses of bulls in the intensive fattening period
dmcf[i]	Program EWDC: Losses of pure-bred ($i = 0$) or cross-bred ($i = 1$) bulls in the fattening period
dmi[i][j]	Incidence of clinical mastitis on day $j+1$ ($j = 0, ..., DL-1$) of lactation $i+1$ ($i = 0, ..., LL-1$)
dmilksum[i]	Change in milk production per cow of category i per reproductive cycle (used for the calculation of the economic weight for milk production), $i = NCP, ...CC$
dot	Total governmental subsidy in the integrated production system per cow and year
dotcalf	Governmental subsidies per weaned calf
dotcowh	Governmental subsidies per performance-tested cow and year
dotcowo	Additional governmental subsidies per cow and year
dotcows	Governmental subsidies per slaughter cow
dotexpm	Governmental subsidies per exported male calf
dotfati	Governmental subsidies per intensively fattened animal
dotfatx	Governmental subsidies per extensively fattened animal
dotmilk	Governmental subsidies per kg milk
dottest	Program EWBC: Governmental subsidies per bull on performance test and per day. Program EWDC: Governmental support for rearing per breeding bull per day
dp[i]	Days in pregnancy for category i ($i = 22, 24, 25, ..., CC-4$)
dpascal	Average interval in days from the end of the summer season to calving
dpasmat	Average interval in days from the end of the summer season to the next mating period
dprfrep	Days of pregnancy of a purchased female for replacement
dresb	Program EWBC: Dressing percentage of bulls
dresb[i]	Program EWDC: Dressing percentage of pure-bred ($i = 0$) or cross-bred ($i = 1$) bulls
dresc	Program EWBC: Dressing percentage of castrates
dresc[i]	Program EWDC: Dressing percentage of pure-bred ($i = 0$) or cross-bred ($i = 1$) castrates
drescw	Dressing percentage of cows

dresh Program EWBC: Dressing percentage of heifers

dresh[i] Program EWDC: Dressing percentage of pure-bred ($i = 0$) and cross-bred ($i = 1$) heifers

dryf[i] Dry matter per kg feed ration for intensively fattened animals of category i (Program EWBC: $i = 4, 5, 6, 12, 13, 14, 15, 16, 17$, Program EWDC: $i = 1, ..., CT$)

dryf10 Dry matter per kg feed ration for breeding bulls from the end of the rearing period of calves till selling

dryf2[i] Dry matter per kg feed ration for calves of category i ($i = 3, 8, 9, 10, CC+3, CC+8, CC+9, CC+10$) in the second feeding period within the rearing period

dryfwf[i] Dry matter per kg feed ration for reared female calves in the first feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

dryfwf2[i] Dry matter per kg feed ration for reared female calves in the second feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

dryfwm[i] Dry matter per kg feed ration for reared male calves in the first feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

dryfwm2[i] Dry matter per kg feed ration for reared male calves in the second feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

dryfx[i] Dry matter per kg feed ration for fattening animals of category i ($i = 5, 6, 12, 13, 16, 17$) after extensive fattening on pasture

dryhayha Amount of dry matter per ha of pasture land (without losses caused by grazing animals)

drys[i] Dry matter per kg summer feed ration for animals of category i ($i = 1, ..., CC$ except $4, 14, 15$)

dryt Dry matter per kg feed ration of breeding bulls in the performance test

drytb Dry matter content per kg winter feed ration of breeding bulls before the performance test

drytse Dry matter per kg feed ration of breeding bulls after the performance test

dryw[i] Dry matter per kg winter feed ration for animals of category i ($i = 1, ..., CC$ except $4, 14, 15$)

ds[i] Lenght (in days) of the summer period for category i ($i = 3, 8, 9, 25, ..., CC$)

ds0[i] Lenght (in days) of the "zeroeth" summer feeding period[20] after weaning for category i ($i = CC + 1, \ldots, CC + 10$)

ds1[i] Lenght (in days) of the 1st summer feeding period after weaning for category i ($i = CC + 1, CC + 2, CC + 9$)

[20] This period occurs only if calves are weaned before the end of the pasture period.

ds2[i] Lenght (in days) of the 2nd summer feeding period after weaning for category i ($i = CC + 2, CC + 3, CC + 10$)

ds3[i] Lenght (in days) of the 3rd summer feeding period after weaning for category i ($i = CC + 3, CC + 6$)

dsd[i] Days dry in the summer period for category i ($i = 25, ..., CC$)

dsl[i] Days of lactation in the summer period for cow category i ($i = 25, ..., CC$) and available for calves of category i ($i = 3, 8, 9$)

dslg Days from reaching mature weight to culling of breeding bulls

dsmp Date of starting the mating period

dsnm2 Date of starting the second part of mating period (start of 2nd oestrus within the mating period)

dsnm3 Date of starting the third part of mating period (start of 3rd oestrus within the mating period)

dsp[i] Days of pregnancy in the summer period for category i ($i = 22, CC + 9$)

dst Days from weaning to the start of the performance test for bulls

dsx Days of the pasture summer period in extensive feeding of heifers or castrates

dt Duration (in days) of the performance test for bulls

dtse Days from the end of the performance test to selling bulls

dung[i] Amount of dung produced per animal of category i ($i = 1, ...CT$) per day

dung10 Amount of dung per breeding bull per day (program EWDC)

dungbb Amount of dung per breeding bull in the herd during the winter housing period and per day

dungfi Amount of dung per animal in intensive fattening and per day

dungfx Amount of dung per animal in extensive fattening during the winter housing period and per day

dungwf[i] Amount of dung produced per female calf and per day in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

dungwm[i] Amount of dung produced per male calf and per day in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

dw[i] Length (in days) of the winter period for category i ($i = 3, 8, 9, 18$)

dw0 Date of weaning calves

dw1[i] Length (in days) of the 1st winter feeding period after weaning for category i ($i = 25, ..., CC + 2, CC + 7$)

dw2[i] Length (in days) of the 2nd winter feeding period after weaning for category i ($i = 25, ..., CC, CC + 2, CC + 4, CC + 8$)

dw3[i] Length (in days) of the 3rd winter feeding period after weaning for category i ($i = CC + 3, CC + 5$)

dw4 Length (in days) of the 4th winter feeding period after weaning for category $CC + 6$

dwd[i] Days dry in the winter period for category i ($i = 25, ..., CC$)

dwl[i] Days of lactation in the winter period for category i ($i = 25, ..., CC$)

dwx Days in the winter period in extensive fattening of heifers or castrates

dys[i] Program EWBC: Vector of probabilities of dystocia occurrence in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dys[i][j] Program EWDC: Vector of probabilities of dystocia occurrence per pure-bred ($i = 0$) or cross-bred ($i = 1$) calving in reproductive cycle $j + 1$ ($j = 0, ..., LL - 1$)

dysav Program EWBC: Average probability of dystocia per calving in the herd of the given structure

dysav[i] Program EWDC: Average probability of dystocia per pure-bred ($i = 0$) and cross-bred ($i = 1$) calving in the herd of the given structure

dysavave Average dystocia incidence (calving scores $\geq$ *dyscl*) in the herd per calving

dysavh[i] Average incidence of calving score $i + 1$ ($i = 0, ..., DD - 1$) per calving in the herd

dysavs[i][j][k] Incidence of calving score $i+1$ ($i = 0, ..., DD-1$) per pure-bred ($j = 0$) or cross-bred ($j = 1$) calving in reproductive cycle $k+1$ ($k = 0, ...LL-1$) averaged over sexes

dysc[i] Average dystocia incidence (calving scores $\geq$ *dyscl*) per calving in reproductive cycle $i + 1$ ($i = 0, ...LL - 1$)

dyscl Lowest calving score which is considered to be dystocia

dysf[i] Program EWBC: Vector of probabilities of dystocia occurrence when female is born in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dysf[i][j] Program EWDC: Vector of probabilities of dystocia occurrence when pure-bred ($i = 0$) or cross-bred ($i = 1$) female is born in reproductive cycle $j + 1$ ($j = 0, ..., LL - 1$)

dysff[j][i] Program EWBC: Vector of probabilities of calving score $j + 1$ ($j = 0, ..., DD - 1$) when female is born in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dysff[j][k][i] Program EWDC: Vector of probabilities of calving score $j + 1$ ($j = 0, ..., DD - 1$) when pure-bred ($k = 0$) or cross-bred ($k = 1$) female is born in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dysff0[j][i] Original values of $dysff[j][i]$ (Must be stored during the calculation of economic weights.)

dysffl[j] Needed for the calculation of economic weights

dysffld[j] Needed for the calculation of economic weights

dysfffldl[j] Needed for the calculation of economic weights

dysfffldr[j] Needed for the calculation of economic weights

dysfffll[j] Needed for the calculation of economic weights

dysfffmc Program EWBC: Mean score for calving performance for female calves

dysfffmc[j] Program EWDC: Mean score for calving performance for pure-bred ($j = 0$) or cross-bred ($j = 1$) female calves

dysfffql[j] Needed for the calculation of economic weights

dysfffqm[j] Needed for the calculation of economic weights

dysfffqr[j] Needed for the calculation of economic weights

dysfffr[j] Needed for the calculation of economic weights

dysm[i] Program EWBC: Vector of probabilities of dystocia occurrence when male is born in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dysm[i][j] Program EWDC: Vector of probabilities of dystocia occurrence when pure-bred ($i = 0$) or cross-bred ($i = 1$) male is born in reproductive cycle $j + 1$ ($j = 0, ..., LL - 1$)

dysmat[i] Vector of probabilities that cows having dystocia in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) will be mated in the following mating period

dysmm[j][i] Program EWBC: Vector of probabilities of calving score $j + 1$ ($j = 0, ..., DD - 1$) when male is born in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dysmm[j][k][i] Program EWDC: Vector of probabilities of calving score $j + 1$ ($j = 0, ..., DD - 1$) when pure-bred ($k = 0$) or cross-bred ($k = 1$) male is born in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

dysmm0[j][i] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmm0[j][k][i] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmml[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmml[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmld[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmld[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmldl[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmldl[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmldr[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmldr[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmll[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmll[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmlmc Program EWBC: Mean score for calving performance for male calves

dysmmlmc[j] Program EWDC: Mean score for calving performance for pure-bred ($j = 0$) or cross-bred ($j = 1$) male calves

dysmmlql[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmlql[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmlqm[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmlqm[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmlqr[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmlqr[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysmmlr[j] Program EWBC: Needed for the calculation of the economic weight for calving performance

dysmmlr[j][k] Program EWDC: Needed for the calculation of the economic weight for calving performance

dysscore[j] Occurrence of calving score $j + 1$ per calving ($j = 0, ..., DD - 1$)

dysscoreav Program EWBC: Average calving score in the herd

dysscoreav[i] Program EWDC: Average calving score in the herd for pure-bred ($i = 0$) or cross-bred ($i = 1$) calves

dysscoreavf[i] Program EWDC: Average calving score in the herd for pure-bred ($i = 0$) or cross-bred ($i = 1$) female calves

dysscoreavm[i] Program EWDC: Average calving score in the herd for pure-bred ($i = 0$) or cross-bred ($i = 1$) male calves

ecm Energy and protein requirement per kg milk with given fat and protein content

ecr2nmc Conception rate of cows in the 2nd oestrus during the second part of the mating period for cows not having dystocia in reproductive cycles 1 to $LL - 1$ expressed as proportion of cows not being pregnant after the 1st oestrus

ecr3nmc Conception rate of cows in the 3rd oestrus during the third part of the mating period for cows not having dystocia in reproductive cycles 1 to $LL-1$ expressed as proportion of cows not being pregnant after the 2nd oestrus

ecrinc Program EWBC: Conception rate of cows in the 1st oestrus during the first part of the mating period for cows not having dystocia in reproductive cycles 1 to $LL-1$ expressed as proportion of cows mated in this oestrus

ecrinc[i] Program EWDC: Conception rate after insemination i+1 ($i = 0, ..., inmax-1$) for cows not having dystocia in reproductive cycles 1 to LL

edf[i] Net energy per kg dry matter of feed ration for animal of category i (Program EWBC:$i = 4, 5, 6, 12, 13, 14, 15, 16, 17$, Program EWDC: $i = 1, ..., CT$)

edf10 Net energy content per kg dry matter of feed ration for breeding bulls from the end of the rearing period of calves till selling

edf2[i] Net energy per kg dry matter of feed ration for calves of category i ($i = 3, 8, 9, 10, CC+3, CC+8, CC+9, CC+10$) in the second feeding period within the rearing period

edfwf[i] Net energy per kg dry matter of feed ration for female calves in the first feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

edfwf2[i] Net energy per kg dry matter of feed ration for female calves in the second feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

edfwm[i] Net energy per kg dry matter of feed ration for male calves in the first feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

edfwm2[i] Net energy per kg dry matter of feed ration for male calves in the second feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

edfx[i] Net energy per kg dry matter of feed ration for fattened animals of category i ($i = 12, 17$) after extensive fattening on pasture

eds[i] Net energy per kg dry matter of summer feed ration for animals of category i ($i = 1, ..., CC$ except $4, 14, 15$)

edt Net energy per kg dry matter of feed ration for breeding bulls in the performance test

edtb Net energy per kg dry matter of feed ration for breeding bulls before the performance test

edtse Net energy per kg dry matter of feed ration for breeding bulls after the performance test

edw[i] Net energy per kg dry matter of winter feed ration for animals of category i ($i = 1, ..., CC$ except $4, 14, 15$)

ew[i] Program EWBC: Economic value for trait i ($i = 1, ..., 29$) calculated for a change in the trait of $\pm 0.5\%$ (for numbering of traits see Section A.2 on page 98)

ew[i][j] Program EWDC: Economic values for trait i calculated for a change in the trait of $\pm 0.5\%$ ($i = 1, ..., 37$, for numbering of traits see Section A.2 on page 98) in progeny group j (pure-bred dairy progeny: $j = 0$, cross-bred beef x dairy progeny: $j = 1$, cross-bred progeny of cows in System 3: $j = 2$) expressed per dairy cow in Production System 4 (for $j = 0$ and $j = 1$) or per cross-bred cow in System 3 (for $j = 2$)

ew0[i] Program EWBC: Economic value for trait i ($i = 1, ..., 29$) calculated for a change in the trait of $\pm 1\%$

ew0[i][j] Program EWDC: Economic value for trait i ($i = 1, ..., 37$) calculated for a change in the trait of $\pm 1\%$

ewc[i][j] Program EWDC: Economic values for trait i in pure-bred dairy progeny expressed per pure-bred dairy calving (per cow calved after mating with dairy bulls, $j = 0$) or in cross-bred progeny expressed per cross-bred calving (per cow calved after mating with beef bulls, $j = 1$)

ewd[i] Economic weight for direct traits i (Program EWBC: $i = 1, ..., 29$, Program EWDC: $i = 1, ..., 37$)

ewdiff[i] Program EWBC: Difference in economic values for trait i ($i = 1, ..., 29$) expressed in per cent: $ewdiff[i] = 100 * (ew0[i] - ew[i])/ew[i]$

ewdiff[i][j] Program EWDC: Difference in economic values for trait i ($i = 1, ..., 37$) and progeny group j ($j = 0, 1$), for detail see variable ew[i][j]) expressed in per cent: $ewdiff[i][j] = 100 * (ew0[i][j] - ew[i][j])/ew[i][j]$

ewm[i] Economic weight for maternal traits (Program EWBC: $i = 1, ..., 29$, Program EWDC: $i = 1, ..., 37$)

ewopt Program EWDC: Option for the calculation of economic values (see Section 4.1.3)

ewwd[i][j] Program EWDC: Temporary variable needed for the calculation of economic values of direct effects

ewwm[i][j] Program EWDC: Temporary variable needed for the calculation of economic values of maternal effects

exfc Program EWBC: Female calves sold expressed as proportion of surplus female calves. Program EWDC: cross-bred female calves sold expressed as proportion of surplus cross-bred female calves

exmc Male calves sold expressed as proportion of male weaned calves

f[i] Program EWBC: Fresh feed requirement per animal in intensive fattening for category i ($i = 4, 5, 6, 12, 13, 14, 15, 16, 17$). Program EWDC: Fresh feed requirement per animal of category i ($i = 1, ..., CT$)

f10 Program EWDC: Fresh feed requirement per animal of category 10 from the end of the rearing period of calves till selling

f2[i] Fresh feed requirement per calf of category i ($i = 3, 8, 9, 10, CC+3, CC+8, CC+9, CC+10$) in the second feeding period within the rearing period

fas[i]	Winter fresh feed requirement per animal of category i ($i = 5, 6, 12, 13, 16, 17$) for extensively fattened animals after pasture
fase[i]	Winter fresh feed requirement per animal of category i ($i = 5, 6, 12, 13, 16, 17$) for extensively fattened animals after pasture calculated on the base of the energy requirement
faspdi[i]	Winter fresh feed requirement per animal of category i ($i = 5, 6, 12, 13, 16, 17$) for extensively fattened animals after pasture calculated on the base of the protein requirement
fat	Fat content in milk
fat305ave	305d fat yield (kg)
fatkg	Fat yield (kg) produced over the whole lactation
fbbs	Fresh feed requirement in the summer period per breeding bull from purchase to culling
fbbse	Fresh feed requirement in the summer period calculated on the base of the energy requirement per breeding bull from purchase to culling
fbbspdi	Fresh feed requirement in the summer period calculated on the base of the protein requirement per breeding bull from purchase to culling
fbbw	Fresh feed requirement in the winter period per bull from purchase to culling
fbbwe	Fresh feed requirement in the winter period calculated on the base of the energy requirement per breeding bull from purchase to culling
fbbwpdi	Fresh feed requirement the in winter period calculated on the base of the protein requirement per breeding bull from purchase to culling
fe[i]	Program EWBC: Fresh feed requirement per animal of category i ($i = 4, 5, 6, 12, 13, 14, 15, 16, 17$) in intensive fattening calculated on the base of the energy requirement. Program EWDC: Fresh feed requirement per animal of category i ($i = 1, ..., CT$) calculated on the base of the energy requirement
fe10	Program EWDC: Fresh feed requirement calculated on the base of the energy requirement per animal of category 10 from the end of the rearing period of calves till selling
fe2[i]	Fresh feed requirement per calf of category i ($i = 3, 8, 9, 10, CC{+}3, CC{+}8, CC{+}9, CC{+}10$) in the second feeding period within the rearing period calculated on the base of the net energy requirement
feedcost	Way of calculating the feeding cost
feedlot	Program EWBC: Type of fattening (1-intensive, 2-extensive)
fewf[i]	Fresh feed requirement per female calf in the first feeding period within the rearing period calculated on the base of the net energy requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
fewf2[i]	Fresh feed requirement per female calf in the second feeding period within the rearing period calculated on the base of the net energy requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fewm[i] Fresh feed requirement per male calf in the first feeding period within the rearing period calculated on the base of the net energy requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fewm2[i] Fresh feed requirement per male calf in the second feeding period calculated on the base of the net energy requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

ffww[i] Fresh feed requirement in the winter period per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$)

fix[i] Fixed cost per day and animal of category i ($i = 1, ...CT$)

fix10 Fixed cost per breeding bull per day

fixwf[i] Fixed cost per day per female reared calf ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fixwm[i] Fixed cost per day per male reared calf ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fixcbb Fixed cost per breeding bull in the herd per day

fixcbbt Total fixed cost per breeding bull from purchase to culling

fixcbt Fixed cost per breeding bull in performance test, per day

fixcc Fixed cost per cow and day (including calf to weaning)

fixcfi Fixed cost per animal and day in intensive fattening

fixcfx Fixed cost per animal and day in extensive fattening

fixcrh Fixed cost per replacement heifer and day, from weaning to calving

fpdi[i] Program EWBC: Fresh feed requirement per animal of category i ($i = 4, 5, 6, 12, 13, 14, 15, 16, 17$) in intensive fattening calculated on the base of the protein requirement. Program EWDC: Fresh feed requirement per animal of category i ($i = 1, ..., CT$) calculated on the base of the protein requirement

fpdi10 Program EWDC: Fresh feed requirement calculated on the base of the protein requirement per animal of category 10 from the end of the rearing period of calves till selling

fpdi2[i] Fresh feed requirement per calf of category i ($i = 3, 8, 9, 10, CC+3, CC+8, CC+9, CC+10$) in the second feeding period within the rearing period calculated on the base of the protein requirement

fpdiwf[i] Fresh feed requirement per female calf in the first feeding period within the rearing period calculated on the base of the protein requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fpdiwf2[i] Fresh feed requirement per female calf in the second feeding period within the rearing period calculated on the base of the protein requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fpdiwm[i] Fresh feed requirement per male calf in the first feeding period within the rearing period calculated on the base of the protein requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fpdiwm2[i] Fresh feed requirement per male calf in the second feeding period within the rearing period calculated on the base of the protein requirement ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fs[i] Fresh feed requirement in the summer period per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$)

fse[i] Fresh feed requirement in the summer period calculated on the base of the energy requirement per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$)

fspdi[i] Fresh feed requirement in the summer period calculated on the base of the protein requirement per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$)

ft Fresh feed requirement per bull in the performance test

ftb Fresh feed requirement per bull from weaning to the begin of the performance test

ftbe Fresh feed requirement calculated on the base of the energy requirement per bull from weaning to the begin of the performance test

ftbpdi Fresh feed requirement in the summer period calculated on the base of the protein requirement per bull from weaning to the begin of the performance test

fte Fresh feed requirement calculated on the base of the energy requirement per bull in the performance test

ftpdi Fresh feed requirement in the summer period calculated on the base of the protein requirement per bull in the performance test

fts Fresh feed requirement per bull from the end of the performance test to selling

ftse Fresh feed requirement per bull from the end of the performance test to selling calculated on the base of the energy requirement

ftsepdi Fresh feed requirement per bull from the end of the performance test to selling calculated on the base of the protein requirement

fwe[i] Fresh feed requirement in the winter period calculated on the base of the energy requirement per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$)

fwf[i] Fresh feed requirement per female calf in the first feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fwf2[i] Fresh feed requirement per female calf in the second feeding period within the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

fwm[i] Fresh feed requirement per male calf in the first feeding period within the rearing period ($i = 0$: pure-bred animals, $i =$ 1cross-bred animals)

fwm2[i] Fresh feed requirement per male calf in the second feeding period within the rearing period ($i = 0$: pure-bred animals, $i =$ 1cross-bred animals)

fwpdi[i] Fresh feed requirement in the winter period calculated on the base of the protein requirement per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$)

gene_flow Sex group for which gene flow is calculated (Program EWBC: 1-sires, 2-dams, Program EWDC: 1-dairy sires, 2-dairy dams, 3-beef sires)

G Program EWBC: Maximal number of categories of animals including subcategories + 1

GG Number of categories of animals including subcategories of progeny, $GG = 6(LL - 1) + 4 + 24 + 10 = CC + 10$

h1mpf Heifers culled after the 1st mating period after their weaning for failure to conceive expressed as proportion of heifers which entered the 1st mating period

h1mprp Heifers staying in the herd to the 2nd mating period (not pregnant or not mated) expressed as proportion of heifers which entered the 1st mating period

h2mpf Heifers culled after the 2nd mating period for failure to conceive expressed as proportion of heifers which entered the 1st mating period

h2mprp Heifers staying in the herd to the 3rd mating period (not pregnant or not mated) expressed as proportion of heifers which entered the 1st mating period

h3mpf Heifers culled after the 3rd mating period for failure to conceive expressed as proportion of heifers entered the 1st mating period

hcmat1 Heifers culled for failure to conceive after their 1st mating period expressed as proportion of heifers not being pregnant in their 1st mating period

hcmat1p Heifers culled after the 1st mating period for failure to conceive expressed as proportion of heifers culled after all mating periods for heifers (maximally 3 periods)

hcmat2 Heifers culled for failure to conceive after their 2nd mating period expressed as proportion of heifers not being pregnant in their 2nd mating period

hcmat2p Heifers culled for failure to conceive after their 2nd mating period expressed as proportion of heifers culled after all mating periods for heifers (maximally 3 periods)

hcmat3p Heifers culled for failure to conceive after their 3rd mating period expressed as proportion of heifers culled after all mating periods for heifers (maximally 3 periods)

hcon1mat Heifers pregnant in their 1st mating period after weaning expressed as proportion of heifers having 1st calving (from all pregnant heifers)

hcon2mat Heifers conceived in their 2nd mating period expressed as proportion of heifers having 1st calving

hcon3mat Heifers conceived in their 3rd mating period expressed as proportion of heifers having 1st calving

hd[i]	Vector of the numbers of expressions for direct traits ($i = 1, ..., acd + acs + 2$), see Section 2.8
herdbook	Fraction of performance-tested cows
hm[i]	Vector of the numbers of expressions for maternal traits ($i = 1, ..., acd + acs + 2$), see Section 2.8
hmpf	Program EWBC: Heifers totally culled after the 1st, 2nd and 3rd mating periods expressed as proportion of heifers entered the 1st mating period. Program EWDC: Heifers culled because of no pregnancy after maximum number of inseminations
i	Index variable
i1	Index variable
i2	Index variable
i3	Index variable
i4	Upper limit for the number of categories ($i4 = C1$ for $cb = 0$ and $i4 = C$ for $cb = 1$)
inint	Interval between two subsequent inseminations
inmax	Maximal number of inseminations per cow after calving
inmaxh	Maximal number of inseminations per heifer
INS	Program EWDC: Maximal number of inseminations
insc	Mating type for cows (1: AI is applied at least in the 1st oestrus in the mating period, 2: natural mating only)
insh	Mating type for heifers (1: AI is applied at least in the 1st oestrus in the mating period, 2: natural mating only)
intcm	Average length of interval between calving and the beginning of the mating period
intcmc	Average length of interval from calving to mating for cows (average from all reproductive cycles)
intconc[i]	Interval between the 1st insemination and conception of cows in reproductive cycle $i + 1$ ($i = 0, ...LL - 2$)
intconh	Interval between the 1st insemination and conception of heifers
ircmy[i]	Incidence rate of clinical mastitis (number of clinical mastitis cases) per cow-year at risk in lactation $i + 1$ ($i = 0, ..., LL - 1$)
J	Program EWDC: Takes value 2
j	Index variable
j1	Index variable
ja	Temporary variable in Program EWDC
jb	Temporary variable in Program EWDC
JJ	Program EWBC: Number of classes for calving performance

jj	Index variable
k	Index variable
k2	Coefficient connected with the lactation curve (for details see Section 2.3.1)
k3	Coefficient connected with the lactation curve (for details see Section 2.3.1)
k4	Coefficient connected with the lactation curve (for details see Section 2.3.1)
kbd	Correction coefficient for breed energy requirement for maintenance for dry cows
kbl	Correction coefficient for breed energy requirement for maintenance for lactating cows
kbwmf	Program EWBC: Ratio of birth weight of male calves to birth weight of female calves
kbwmf[i]	Program EWDC: Ratio of birth weight of male calves to birth weight of female calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
kce	Program EWBC: Correction coefficient for energy requirement according to the maturity type of castrates in fattening (fixed value in the program according to the maturity type of progeny)
kce[i]	Program EWDC: Correction coefficient for energy requirement according to the maturity type of castrates ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
kcon2c	Ratio of conception rate in the 2nd oestrus to conception rate in the 1st oestrus of cows
kcon2h	Ratio of conception rate in the 2nd oestrus to conception rate in the 1st oestrus of heifers
kcon3c	Ratio of conception rate in the 3rd oestrus to conception rate in the 1st oestrus of cows
kcon3h	Ratio of conception rate in the 3rd oestrus to conception rate in the 1st oestrus of heifers
kconc[i]	Ratio of the conception rate of cows after insemination $i + 1$ ($i = 0, ..., inmax - 1$) to conception rate after the 1st insemination
kconh[i]	Ratio of the conception rate of heifers after insemination $i + 1$ ($i = 0, ..., inmax - 1$) to conception rate after the 1st insemination
kcp	Program EWBC: Correction coefficient for protein requirement according to the maturity type of castrates in fattening (fixed value in the program according to the maturity type of progeny)
kcp[i]	Program EWDC: Correction coefficient for protein requirement according to the maturity type of castrates ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
kdgfxwas	Ratio of average daily gain of heifers in extensive fattening after pasture to average daily gain of heifers in the winter period after weaning

kdgfxws Ratio of average daily gain of heifers in extensive fattening in the pasture period to average daily gain of heifers in the winter period after weaning

kdgxascf Ratio of average daily gain of castrates after pasture to average daily gain of heifers in the winter period after weaning, extensive fattening

kdgxscf Ratio of average daily gain of castrates on pasture to average daily gain of heifers in the winter period after weaning, extensive fattening

kdgxwcf Ratio of average daily gain of castrates in the winter period to average daily gain of heifers in the winter period after weaning, extensive fattening

kdresb Dressing percentage of bulls not reaching the demanded slaughter weight as proportion of dressing percentage of bulls reaching slaughter weight

kdresbh Program EWBC: Ratio of dressing percentage of bulls at slaughter to dressing percentage of heifers at slaughter

kdresbh[i] Program EWDC: Ratio of dressing percentage of bulls at slaughter to dressing percentage of heifers at slaughter ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kdresc Dressing percentage of castrates not reaching the demanded slaughter weight as proportion of dressing percentage of castrates reaching slaughter weight

kdresch Program EWBC: Ratio of dressing percentage of castrates at slaughter to dressing percentage of heifers at slaughter

kdresch[i] Program EWDC: Ratio of dressing percentage of castrates at slaughter to dressing percentage of heifers at slaughter ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kdresh Dressing percentage of heifers not reaching the demanded slaughter weight as proportion of dressing percentage of heifers reaching slaughter weight

kdrscwh Ratio of dressing percentage of cows at slaughter to dressing percentage of heifers at slaughter

kdysfc Ratio of dystocia occurrence in heifers to dystocia occurrence in cows

kff Correction coefficient for feed requirement according to feed losses in intensive fattening

kfpa Correction coefficient for feed requirement according to feed losses for grazing animals

kfw Program EWBC: Correction coefficient for feed requirement according to feed losses for winter feeding in the pasture system. Program EWDC: Correction coefficient for feed requirement according to feed losses for indoor systems (cows, heifers and calves)

kg10 Program EWDC: Ratio of average daily gain of breeding bulls to average daily gain of heifers in fattening

kgaincf Program EWBC: Ratio of average daily gain of castrates in fattening to average daily gain of heifers in fattening

kgaincf[i] Program EWDC: Ratio of average daily gain of castrates in fattening to average daily gain of heifers in fattening ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kgainmf Program EWBC: Ratio of average daily gain of bulls in fattening to average daily gain of heifers in fattening

kgainmf[i] Program EWDC: Ratio of average daily gain of bulls in fattening to average daily gain of heifers in fattening ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kgcmf[i] Ratio of average daily gain of male calves to average daily gain of female calves from birth to the end of the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kgcon1mf Ratio of average daily gain of male calves to average daily gain of female calves from birth to the first control

kgcon2mf Ratio of average daily gain of male calves to average daily gain of female calves from the first to the second control

kgcon3mf Ratio of average daily gain of male calves to average daily gain of female calves from the second to the third control

kghccf[i] Ratio of average daily gain of heifers from the 1st mating to calving to average daily gain of female calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kghcf[i] Ratio of average daily gain of heifers from the end of the rearing period to the 1st mating to average daily gain of female calves in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

khe Program EWBC: Correction coefficient for energy requirement according to the maturity type of heifers in fattening (fixed value in the program according to the maturity type of progeny)

khp Program EWBC: Correction coefficient for protein requirement according to the maturity type of heifers in fattening (fixed value in the program according to the maturity type of progeny)

km Coefficient connected with the lactation curve (for details see Section 2.3.1)

kmatc Ratio of the weight of dairy heifers at the 1st mating to mature weight of dairy cows

kmcwhmin Program EWBC: Coefficient ($= whmin/mcw$)

kmwbc Ratio of mature weight of bulls to mature weight of cows of the same breed

kp21 Program EWBC: Ratio of the probability that a life born calf dies from calving to 48 hours after calving to the probability of still born calves

kp21[i] Program EWDC: Ratio of the probability that a life born dairy ($i = 0$) or cross-bred ($i = 1$) calf dies from calving to 48 hours after calving to the probability of still born calves

kpm1 Program EWBC: Ratio of the probability of still born male calves to the probability of still born female calves

kpm1[i] Program EWDC: Ratio of the probability of still born male calves to the probability of still born female calves ($i = 0$: pure-bred calves, $i = 1$: cross-bred calves)

kpm2 Program EWBC: Ratio of the probability that a life born male calf dies from calving to 48 hours after calving to the probability that a life born female calf dies from calving to 48 hours after calving

kpm2[i] Program EWDC: Ratio of the probability that a life born male calf dies from calving to 48 hours after calving to the probability that a life born female calf dies from calving to 48 hours after calving ($i = 0$: pure-bred calves, $i = 1$: cross-bred calves)

kpr[i] Coefficient for price decrease for animals of category i ($i = 13, 15, 16$, and $21 + 6 * r$ with $r = 1, ..., LL$ in programs EWBC and EWDC, and $i = CC + 13, CC + 15, CC + 16$ in Program EWDC only) involuntarily culled

kslb Program EWBC: Coefficient to calculate the optimal slaughter weight of intensively fattened bulls from the mature weight of cows (ratio of slaughter weight of fattened bulls to mature weight of cows)

kslb[i] Program EWDC: Coefficient to calculate the optimal slaughter weight of intensively fattened bulls from the mature weight of cows (ratio of slaughter weight of fattened bulls to mature weight of cows, $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kslc Program EWBC: Coefficient to calculate the optimal slaughter weight of intensively fattened castrates from the mature weight of cows (ratio of slaughter weight of fattened castrates to mature weight of cows)

kslc[i] Program EWDC: Coefficient to calculate the optimal slaughter weight of intensively fattened castrates from the mature weight of cows (ratio of slaughter weight of fattened castrates to mature weight of cows, $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kslcx Coefficient to calculate the optimal slaughter weight of extensively fattened castrates from the mature weight of cows

kslh Program EWBC: Coefficient to calculate the optimal slaughter weight of intensively fattened heifers from the mature weight of cows (ratio of slaughter weight of fattened heifers to mature weight of cows)

kslh[i] Program EWDC: Coefficient to calculate the optimal slaughter weight of intensively fattened heifers from the mature weight of cows (ratio of slaughter weight of fattened heifers to mature weight of cows, $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

kslhx Coefficient to calculate the optimal slaughter weight of extensively fattened heifers from the mature weight of cows

kt Correction coefficient for energy requirement for maintenance according to technology (kt takes either the value of ktb or of ktf)

ktb Correction coefficient for energy requirement for maintenance according to technology - bind technology

ktf Correction coefficient for energy requirement for maintenance according to technology - free technology

ktp	Correction coefficient for energy requirement for maintenance according to technology - pasture
L	Maximal number of reproductive cycles
labherd	Herdsman's time dealing with an average clinical mastitis case (treatment, separate milking etc.)
labvet	Veterinarian's time spend per average clinical mastitis case
l_inv	Length of the investment period (symbol T is used for this variable in Section 2.8)
l1[i]	Vector of relative frequencies of the individual categories of animals when the cow herd is in the stationary state. For $i = 25, ..., CC$, it holds $l1[i] = l2[i - 24]$ with $\sum_{i=25}^{CC} l1[i] = 1$. The remaining elements of the vector ($i = 1, ..., 24$ for all systems and $i = CC + 1, ..., CT$ for Program EWDC only) are the relative frequencies of the progeny (on a per year basis) which are derived from the frequencies of the cow categories. Assuming that a cow has one calf per year on average, the sum of all elements will be approximately 2.
l2[i]	Probability that in the stationary state of the whole production system, a cow belongs to category $i + 24$ ($i = 1, ..., TT$)
l2_0[i]	The same as before
L3	Program EWDC: Number of reproductive cycles in System 3 (read from file FROM1_3.TXT - see Section 5.1.3 on page 94)
l3[i]	Cows calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) expressed as proportion of cows entering any reproductive cycle ($\sum_{i=0}^{LL-1} l3[i] \leq 1$)
l4[i]	Cows entering reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) expressed as proportion of cows entering any reproductive cycle ($\sum_{i=0}^{LL-1} l4[i] = 1$)
labdys[j]	Stock-man hours connected with calving difficulty score $j + 1$ ($j = 0, ..., DD - 1$)
lactcur	Way of calculating the parameters for the lactation curve (1: parameters are known and are input parameters, 2: parameters are calculated in the program)
lengbt	Length of the performance test for bulls
lghrcyc	Length of the reproductive cycle (fixed value in the program)
lgpre	Length of pregnancy
life[i]	Productive lifetime of a cow of category i ($i = 25, ..., CC$)
lifebb	Productive lifetime of breeding bulls in numbers of reproductive cycles of cows
LL	Number of lactations (reproductive cycles)
lm2	Day of peak milk of two-years old cows (parameter LM_2 in Section 2.3.1)
lm3	Day of peak milk of three-years old cows (parameter LM_3 in Section 2.3.1)

lm4 Day of peak milk of four-years old cows (parameter LM_4 in Section 2.3.1)

lmm Day of peak milk of cows older than four years (parameter LM_m in Section 2.3.1)

losc Average cow losses in the herd (sum of cows died and cows culled for health problems other than dystocia)

losff Losses of feed in intensive fattening

losfpa Losses of feed on pasture

losfw Program EWBC: Probability that a born female calf dies from 48 hours after calving to weaning

losfw[i] Program EWDC: Probability that a born female calf dies from 48 hours after calving to the end of the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

loshin[i] Losses of heifers from the end of the rearing period to the 1st insemination ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

losmw Program EWBC: Probability that a born male calf dies from 48 hours after calving to weaning

losmw[i] Program EWDC: Probability that a born male calf dies from 48 hours after calving to the end of the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

lossmilk losses for discarded milk due to clinical mastitis per cow and year

losstotal total financial loss from clinical mastitis per cow and year

loswf Losses of feed in winter feeding (Program EWBC) or in indoor feeding of cows, calves and heifers (Program EWDC)

m_gf[i] Vector of dimension $acs + acd + 2$ (in Program EWBC) or of dimension acm (in Program EWDC) used in the calculation of gene flow (see Section 2.8)

m_gf0[i] Vector $\mathbf{m_k^{[t]}}$ of dimension $acs + acd + 2$ (in Program EWBC) or of dimension acm (in Program EWDC) used in the calculation of gene flow at the end of the investment period ($t = T$, see Section 2.8)

m_sum[i] Vector $\sum_{t=1}^{T} \mathbf{m_k^{[t]}}(1+r)^{-t}$ of dimension $acs+acd+2$ (in Program EWBC) or of dimension acm (in Program EWDC) used in the calculation of gene flow (see Section 2.8). The vector contains the number of discounted expressions for the individual age-sex groups.

mast_inc Program EWDC: Variable indicating if data from mastitis incidence are available ($mast\_inc = 1$) or not ($mast\_inc = 0$)

matcross Maturity type of cross-bred progeny (1-early, 2-middle, 3-late)

matpur Maturity type of pure-bred progeny (1-early, 2-middle, 3-late)

maturity Maturity type of progeny (1-early, 2-middle, 3-late)

mcw Mature weight of cows (weight of cows after the 3rd calving)

mcwb	Mature weight of beef cows their sons are used for terminal crossing (weight of cows after the 3rd calving)
mcwd	Mature weight of dairy cows (weight of cows after the 3rd calving)
milk	Average milk yield per cow and year
milk21	$milk21 = milk305[1]/milk305[0]$
milk31	$milk31 = milk305[2]/milk305[0]$
milk305[i]	305-d milk yield in lactation $i+1$ ($i = 0, ..., LL-1$)
milk305ave	305-d milk yield averaged over lactations
milkprice	Option for the calculation of the milkprice (see Section 4.1.1.14)
milkquota	Indicator variable for quota for milk market (0: no quota, 1: quota for milk yield only, 2: quota for milk yield and fat content)
milksum[i]	Milk production per cow of category i ($i = 25, ...CC$)
milktot	Total milk production in the herd
milktoth	In the calculation of economic weights: the value of *milktot* for the increased value of the given trait
milktotl	In the calculation of economic weights: the value of *milktot* for the decreased value of the given trait
milktotm	In the calculation of economic weights: keeps the value of *milktot*
min[i]	Mineral requirement per animal of category i ($i = 1, ..., CC$ except $4, 14, 15$) and per day
mo	Temporary variable (month - part of the date)
mp2	Peak milk yield in kg per day for 2-year old cows (on pasture with suckling calf - parameter M_{p2} in Section 2.3.1)
mp3	Peak milk yield in kg per day for 3-year old cows (on pasture with suckling calf - parameter M_{p3} in Section 2.3.1)
mp4	Peak milk yield in kg per day for 4-year old cows (on pasture with suckling calf - parameter M_{p4} in Section 2.3.1)
mpm	Peak milk yield in kg per day for cows older than 4 years (on pasture with suckling calf - parameter M_{pm} in Section 2.3.1)
mpm0	Peak milk in kg per day (on pasture with suckling calf - parameter M_{pm0} in Section 2.3.1)
mSCS	Mean of somatic cell score in the dairy cow population
msel	Bulls selected expressed as proportion of performance-tested bulls
mtest	Program EWBC: Proportion of male weaned calves performance tested
mtest[i]	Program EWDC: Proportion of male calves alive at 48 hours after birth that are sold as breeding males (e.g. to test stations or AI stations, $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
mwb	Mature weight of bulls

mxmc[i]	Proportion of male calves alive at 48 hours after birth that are determined for selling outside of the evaluated production system within each progeny group i ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
n	Number of cow categories
n_sac	Number of sex-age class for which the gene flow will be calculated
n1	Temporary variable (number of variables in the input file)
n2	Temporary variable (number of the input file)
Ncal	Program EWBC: Number of calvings in the herd per cow and reproductive cycle
Ncal[i]	Program EWDC: Number of calvings in the herd per cow and reproductive cycle ($i = 0$: calvings after pure-bred mating, $i = 1$: calvings after cross-bred mating)
Ncalt	Program EWDC: Total number of calvings in the herd per cow and reproductive cycle ($Ncalt = Ncal[0] + Ncal[1]$)
nccf	Program EWBC: Number of fattened castrates slaughtered before reaching the required slaughter weight expressed as proportion of the total number of fattened castrates
nccf[i]	Program EWDC: Number of fattened castrates slaughtered before reaching the required slaughter weight expressed as proportion of the total number of fattened castrates ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
ncows	Number of slaughtered cows per cow and year
NCP	Program EWBC: Number of categories of progeny + 1. Program EWDC: Number of categories of pure-bred (or cross-bred) progeny + 1
ncp[i]	Probability that a calved cow in reproductive cycle i+1 ($i = 0, ..., LL-1$) will be not pregnant after the maximal number of inseminations
nd[i]	Ratio days dry to calving interval in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)
ndaycc	Program EWBC: Average number of days that a cow culled within the reproductive cycle for health problems excluding dystocia stayed in the herd from previous calving
ndaycc[i]	Program EWDC: Average number of days that a cow culled within reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) for health problems excluding dystocia stayed in the herd from previous calving
ndaycd	Program EWBC: Average number of days that a cow died within the reproductive cycle stayed in the herd from previous calving
ndaycd[i]	Program EWDC: Average number of days that a cow died within reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) stayed in the herd from previous calving
ndaycw	Average number of days that a cow culled after calf weaning due to failure to conceive stayed in the herd from previous calving (assuming the cows are culled at the end of the summer season)

ndaydys Average number of days that the cow culled due to dystocia stayed in the herd from previous calving

NDEc[i] Number of discounted expressions for cost in category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$) per cow and reproductive cycle

NDEd Number of discounted expressions for direct traits for the selection group (sires, dams), per cow and reproductive cycle

NDEdys Number of discounted expressions for dystocia cost for the selection group (sires, dams), per cow and reproductive cycle

NDEm Number of discounted expressions for maternal traits for the selection group (sires, dams), per cow and reproductive cycle

NDEr[i] Number of discounted expressions for revenues in category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $(i = 1, ..., CT)$, per cow and reproductive cycle

ne[i] Total net energy requirement per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

ne10 Program EWDC: Net energy requirement per animal of category 10 from the end of the rearing period of calves till selling

ne2[i] Net energy requirement for a calf of category i $(i = 3, 8, 9, 10, CC + 3, CC + 8, CC + 9, CC + 10)$ in the second feeding period within the rearing period of calves

neas[i] Energy requirement needed for reaching the required slaughter weight of extensively fattened animals of category i $(i = 12, 17)$ after the summer fattening period on pasture

nebbm Energy requirement from purchase to reaching mature weight for breeding bulls

nebbs Energy requirement from purchase to slaughter for breeding bulls in the summer feeding period

nebbsl Energy requirement from reaching mature weight to slaughter for breeding bulls

nebbw Energy requirement from purchase to slaughter for breeding bulls in the winter feeding period

nebt Energy requirement from weaning to the start of the performance test for bulls

neg[i] Net energy requirement for growth per cow of category i $(i = 25, ...CC)$

negs[i] Energy requirement per cow of category i $(i = 25, ..., CC)$ for growth in the summer feeding period

negw[i] Energy requirement per cow of category i $(i = 25, ..., CC)$ for growth in the winter feeding period

nel[i] Net energy requirement for lactation per cow of category i $(i = 25, ..., CC)$

nem[i] Net energy requirement for maintenance per cow of category i $(i = 25, ..., CC)$

nems[i] Energy requirement per cow of category i ($i = 25, ..., CC$) for maintenance in the summer feeding period

nemw[i] Energy requirement per cow of category i ($i = 25, ..., CC$) for maintenance in the winter feeding period

nepc[i] Total energy requirement for pregnancy per animal of category i ($i = 22, 25, ..., CC$)

nes[i] Net energy requirement per animal of category i ($i = 1, ..., CC + 10$ except $4, 14, 15$) in the summer feeding period

nes0[i] Energy requirement in the "zeroeth" summer feeding period[21] after weaning per animal of category i ($i = CC + 1, ..., CC + 10$)

nes1[i] Energy requirement in the 1st summer feeding period after weaning per animal of category i ($i = CC + 2, ..., CC + 6, CC + 8, CC + 10$)

nes2[i] Energy requirement in the 2nd summer feeding period after weaning per animal of category i ($i = CC + 2, CC + 3, CC + 5, CC + 6, CC + 10$)

nes3[i] Energy requirement in the 3rd summer feeding period after weaning per animal of category i ($i = CC + 3, CC + 5, CC + 6$)

nescal[i] Total energy requirement in the summer feeding period per cow of category i ($i = 25, ..., CC$) that had calved in a reproductive cycle

nesl[i] Energy available per calf of category i ($i = 3, 8, 9$) in the summer feeding period from cows' milk ($i = 25, ..., CC$)

nesncal[i] Total energy requirement in the summer feeding period per cow of category i ($i = 25, ..., CC$) that had not calved at the entrance of a reproductive cycle

nesp[i] Energy requirement for pregnancy in the summer feeding period per animal of category i ($i = 20, 22, 25 - CC, CC + 9, CC + 10$)

net Energy requirement per bull in the performance test

netse Energy requirement per bull from the end of the performance test to selling (category 10)

new[i] Net energy requirement per animal of category i ($i = 1, ..., CC + 10$ except $4, 14, 15$) in the winter feeding period

new1[i] Energy requirement in the 1st winter feeding period after weaning per animal of category i ($i = CC + 2, ..., CC + 6, CC + 8, CC + 10$)

new2[i] Energy requirement in the 2nd winter feeding period after weaning per animal of category i ($i = CC + 2, ..., CC + 6, CC + 8, CC + 10$)

new3[i] Energy requirement in the 3rd winter feeding period after weaning per animal of category i ($i = CC + 3, CC + 5, CC + 6$)

new4 Energy requirement in the 4th winter feeding period after weaning for category $CC + 4$

newcal[i] Total energy requirement in the winter feeding per cow of category i ($i = 25, ..., CC$) that had calved in a reproductive cycle

[21] This period occurs only if calves are weaned before the end of the pasture period.

newf[i] Net energy requirement per female calf from birth to the end of the first feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

newf2[i] Net energy requirement per female calf in the second feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

newl[i] Energy available per calf of category i ($i = 3, 8, 9$) in the the winter feeding period from cows' milk ($i = 25, ..., CC$)

newm[i] Net energy requirement per male calf from birth to the end of the first feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

newm2[i] Net energy requirement per male calf in the second feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

newncal[i] Total energy requirement in the winter feeding period per cow of category i ($i = 25, ..., CC$) that had not calved at the entrance of the reproductive cycle

newp[i] Energy requirement for pregnancy in the the winter period per animal of category i ($i = 22, 25, ..., CC$)

NFAT Program EWDC: Maximal number of threshold values for milk fat content in the milk paying system

nfat Number of thresholds for milk fat content in the milk paying system

Nfav Female calves available for fattening or selling as proportion of weaned or reared female calves

Nfc48a Program EWBC: Number of female calves staying alive 48 hours after calving per cow and reproductive cycle

Nfc48a[i] Program EWDC: Number of female calves staying alive 48 hours after calving per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nfcba Program EWBC: Number of female calves born alive per cow and reproductive cycle

Nfcba[i] Program EWDC: Number of female calves born alive per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

nfcf Program EWBC: Fattened heifers slaughtered before reaching the required slaughter weight expressed as proportion of the total number of fattened heifers

nfcf[i] Program EWDC: Fattened heifers slaughtered before reaching the required slaughter weight expressed as proportion of the total number of fattened heifers ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nfcw Program EWBC: Number of female calves weaned per cow and reproductive cycle

Nfcw[i] Program EWDC: Number of female calves reared per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nffa — Program EWBC: Heifers available for fattening per cow and reproductive cycle

Nffa[i] — Program EWDC: Heifers available for fattening per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nfmat — Program EWBC: Number of heifers per cow and reproductive cycle that must enter the first mating period after weaning if no heifers are sold pregnant. Program EWDC: Number of pure-bred heifers per cow and reproductive cycle that must be firstly inseminated if no heifers are sold pregnant

Nfrer — Number of heifers that must be reared per cow and year for herd replacement if no breeding heifers are sold

Nfrp — Replacement heifers expressed as proportion of all born calves

nin[i] — Number of inseminations per female of category i ($i = 22, 24, 25, ...CC-3$)

ninr[i] — Number of inseminations per cow in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

nl[i] — Ratio of days in lactation to calving interval in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

Nmc48a — Program EWBC: Number of male calves staying alive 48 hours after calving per cow and reproductive cycle

Nmc48a[i] — Program EWDC: Number of male calves staying alive 48 hours after calving per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nmcba — Program EWBC: Number of male calves born alive per cow and reproductive cycle

Nmcba[i] — Program EWDC: Number of male calves born alive per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nmcf — Program EWBC: Number of male calves determined for fattening per cow and reproductive cycle

Nmcf[i] — Program EWDC: Number of male calves reared and determined for fattening per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

nmcf — Program EWBC: Number of fattened bulls slaughtered before reaching slaughter weight expressed as proportion of the total number of fattened bulls

nmcf[i] — Program EWDC: Number of fattened bulls slaughtered before reaching slaughter weight expressed as proportion of the total number of fattened bulls ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nmcfb — Program EWBC: Number of male calves fattened as bulls per cow and reproductive cycle

Nmcfb[i] — Program EWDC: Number of male calves fattened as bulls per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nmcfc — Program EWBC: Number of male calves fattened as castrates per cow and reproductive cycle

Nmcfc[i] — Program EWDC: Number of male calves fattened as castrates per cow and reproductive cycle ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

Nmcw — Program EWBC: Number of male calves weaned per cow and reproductive cycle

np[i] — Probability within the given reproductive cycle r that a cow which entered this cycle as a not pregnant cow belongs to the given stage s (for more details see Section 2.2). Let r ($r = 1, ..., LL$) be the number of the reproductive cycle and s ($s = 1, ..., 6$ for $r < LL$ or $s = 1, .., 4$ for $r = LL$) the number of the stage, then $i = 6(r + 3) + s$ and

$$\sum_{i=6(r+3)+1}^{i=6(r+3)+S} np[i] = 1$$

for all r and $S = 6$ (for $r < LL$) or $S = 4$ (for $r = LL$). The variable is defined for $i = 25, ..., CC$.

npc[i] — Cows not pregnant after the mating period in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$) expressed as proportion of cows calving in this cycle

npcsn[i] — Not pregnant cows which stayed in the herd for the next mating period as proportion of all not pregnant cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$) that entered this reproductive cycle as not pregnant cows

npcsp[i] — Not pregnant cows which stayed in the herd for the next mating period as proportion of all not pregnant cows in cycle $i + 1$ ($i = 0, ..., LL - 2$) that entered this reproductive cycle as pregnant cows

nphs — Breeding heifers sold before mating expressed as proportion of surplus female calves

anphsold1 — Program EWBC: Proportion of non-pregnant breeding heifers sold before the first mating period after their weaning

anphsold2 — Program EWBC: Proportion of non-pregnant breeding heifers sold between the first and second mating period after their weaning

NPROT — Program EWDC: Maximal number of threshold values for milk protein content in the milk paying system

nprot — Number of thresholds for milk protein content in the milk paying system

nr — Number of re-inseminations per AI

NSCC — Maximal number of milk quality classes according to somatic cell content in the dairy cow population

nSCC — Number of milk quality classes according to somatic cell content in the dairy cow population

NT — Number of traits + 1

p[i] Program EWBC: Vector of relative frequencies of the individual categories of progeny when the cow herd is in the stationary state. The elements of the vector ($i = 1, ..., 24$) are derived from the frequencies of the cow categories. Assuming that a cow has one calf per year on average, then the sum of all elements will be approximately 1. The value can be enlarged by purchased animals. The values of $p[i]$ are identical to the values of $l[i]$ for $i = 1, ..., 24$.

p[j][i] Program EWDC: The same as $p[i]$ in Program EWBC with additional differentiation between pure-bred ($j = 0$) and cross-bred progeny ($j = 1$), $i = 1, ..., 24$. It holds: $l[i] = p[0][i] + p[1][i]$ for all i.

P1 Maximal number of classes for fleshiness

p1 Number of classes for fleshiness

P2 Maximal number of classes for fat covering

p2 Number of classes for fat covering

Pb[i][j] Program EWBC: Matrix of proportions (in per cent) of bull carcasses in the ith class of fleshiness and the jth class of fat covering; the elements of the matrix add up to 100

Pb[i][j][k] Program EWDC: Matrix of proportions (in per cent) of bull carcasses in commercial classes for fleshiness (i) and fat covering (j) for pure-bred ($k = 0$) or cross-bred animals ($k = 1$)

pc Program EWDC: (when the cross-bred cows in System 3 came from System 4) Number of cross-bred cows in System 3 expressed as proportion of dairy cows in System 4 (that means per dairy cow in System 4)

Pc[i][j] Program EWBC: Matrix of proportions (in per cent) of cow carcasses in the ith class of fleshiness and the jth class of fat covering; the elements of the matrix add up to 100

Pc[i][j][k] Program EWDC: Matrix of proportions (in per cent) of cow carcasses in the ith class of fleshiness and the $j$class of fat covering for pure-bred ($k = 0$) or cross-bred animals ($k = 1$); the elements of the matrix add up to 100[22]

Pc0[i][j] Program EWBC: Temporary variable needed for the calculation of economic weights of fleshiness and fat covering

Pc0[i][j][k] Program EWDC: Temporary variable needed for the calculation of economic weights of fleshiness and fat covering

pcal[i] Calved cows (pregnant in the previous reproductive cycle) in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) expressed as proportion of all cows entered this cycle

pcalc[i] Calved cows (pregnant in the previous reproductive cycle) in category i ($i = 25, ..., CC$) as proportion of all cows in this category

pcdys[i] Probability that a cow will be culled due to health problems after dystocia in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

[22] In the modeled system, only pure-bred cows occur and the matrix is calculated only for $k = 0$.

Pcfc[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfc[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcd[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcd[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcdl[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcdl[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcdr[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcdr[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcl[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcl[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcmc Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcmc[k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcmcb Program EWBC: Mean class for fat covering in bulls

Pcfcmcb[k] Program EWDC: Mean class for fat covering in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) bulls

Pcfcmcc Program EWBC: Mean class for fat covering in cows

Pcfcmcc[k] Program EWDC: Mean class for fat covering in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) cows[23]

Pcfcmcca Program EWBC: Mean class for fat covering in castrates

Pcfcmcca[k] Program EWDC: Mean class for fat covering in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) castrates

Pcfcmch Program EWBC: Mean class for fat covering in heifers

Pcfcmch[k] Program EWBC: Mean class for fat covering in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) heifers

Pcfcql[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

[23] Only calculated for pure-bred dairy cows

Pcfcql[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcqm[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcqm[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcqr[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcqr[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfcr[j] Program EWBC: Needed for the calculation of the economic weight for fat covering

Pcfcr[j][k] Program EWDC: Needed for the calculation of the economic weight for fat covering

Pcfl[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcfl[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcfld[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcfld[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcfldl[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcfldl[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcfldr[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcfldr[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcfll[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcfll[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcflmc Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcflmc[k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcflmcb Program EWBC: Mean class for fleshiness in bulls

Pcflmcb[k] Program EWDC: Mean class for fleshiness in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) bulls

Pcflmcc Program EWBC: Mean class for fleshiness in cows

Pcflmcc[k] Program EWDC: Mean class for fleshiness in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) cows[24]

Pcflmcca Program EWBC: Mean class for fleshiness in castrates

Pcflmcca[k] Program EWDC: Mean class for fleshiness in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) castrates

Pcflmch Program EWBC: Mean class for fleshiness in heifers

Pcflmch[k] Program EWDC: Mean class for fleshiness in pure-bred dairy ($k = 0$) or cross-bred ($k = 1$) heifers

Pcflql[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcflql[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcflqm[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcflqm[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcflqr[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcflqr[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

Pcflr[i] Program EWBC: Needed for the calculation of the economic weight for fleshiness

Pcflr[i][k] Program EWDC: Needed for the calculation of the economic weight for fleshiness

pclos[i] Cow losses within reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$), $pclos[i] = pp[25 + 6i]$

pcmf Program EWBC: Fattened castrates expressed as proportion of male calves intended for fattening

pcmf[i] Program EWDC: Fattened castrates expressed as proportion of male calves intended for fattening ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pconc[i][j] Cows conceiving in reproductive cycle $i + 1$ after the jth insemination as proportion of all conceived cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

pconh[j] Heifers conceiving after the jth insemination as proportion of all conceived heifers

pcross[i] Dairy cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$) mated with beef bulls as proportion of all mated dairy cows in the given reproductive cycle

[24] Only calculated for pure-bred dairy cows

pcrossh Dairy heifers mated with beef bulls as proportion of all mated dairy heifers

Pcs[i][j] Program EWBC: Matrix of proportions (in per cent) of castrate carcasses in the ith class of fleshiness and the $j$class of fat covering; the elements of the matrix add up to 100

Pcs[i][j][k] Program EWDC: Matrix of proportions (in per cent) of castrate carcasses in the ith class of fleshiness and the $j$class of fat covering for pure-bred ($k = 0$) or cross-bred animals ($k = 1$); the elements of the matrix add up to 100

pcul[i] Cows culled within the reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) as proportion of all cows entered the cycle

pdi[i] Total protein requirement per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

pdi10 Program EWDC: Protein requirement per animal of category 10 from the end of the rearing period of calves till selling

pdi2[i] Protein requirement per calf of category i ($i = 3, 8, 9, 10, CC + 3, CC + 8, CC + 9, CC + 10$) in the second feeding period

pdias[i] Protein requirement needed for reaching the required slaughter weight of extensively fattened animals per animal of category i ($i = 12, 17$) after the summer fattening period on pasture

pdibbm Protein requirement per breeding bull from purchase to reaching mature weight

pdibbs Protein requirement per breeding bull from summer feed ration from purchase to slaughter

pdibbsl Protein requirement per breeding bull from summer feed ration from reaching mature weight to slaughter

pdibbw Protein requirement per breeding bull from winter feed ration from purchase to slaughter

pdibt Protein requirement per bull from weaning to the start of the performance test

pdid[i] Protein content per kg dry matter of feed ration for animals of category i ($i = 1, ...CT$)

pdid10 Protein content per kg dry matter of feed ration for breeding bulls from the end of the rearing period of calves till selling

pdid2[i] Protein content per kg dry matter of feed ration for calves of category i ($i = 3, 8, 9, 10, CC + 3, CC + 8, CC + 9, CC + 10$) in the second feeding period

pdidf[i] Protein per kg dry matter of feed ration for intensively fattened animals of category i ($i = 4, 5, 6, 12, 13, 14, 15, 16, 17$)

pdidfx[i] Protein per kg dry matter of feed ration for fattened animals of category i ($i = 12, 17$) in the period after extensive fattening on pasture

pdids[i] Protein per kg dry matter of summer feed ration for animals of category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)

pdidt Protein per kg dry matter of summer feed ration for breeding bulls in the performance test

pdidtb Protein per kg dry matter of feed ration for breeding bulls in the herds from weaning to the start of the performance test

pdidtse Protein per kg dry matter of winter feed ration for breeding bulls from the end of the performance test to selling

pdidw[i] Protein per kg dry matter of winter feed ration for animals of category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)

pdidwf[i] Protein content per kg dry matter of feed ration for female calves in the first feeding period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdidwf2[i] Protein content per kg dry matter of feed ration for female calves in the second feeding period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdidwm[i] Protein content per kg dry matter of feed ration for male calves in the first feeding period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdidwm2[i] Protein content per kg dry matter of feed ration for male calves in the second feeding period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdig[i] Protein requirement for growth per cow of category i ($i = 25, ...CC$)

pdigs[i] Protein requirement per cow of category i ($i = 25, ..., CC$) for growth in the summer feeding period

pdigw[i] Protein requirement per cow of category i ($i = 25, ..., CC$) for growth in the winter feeding period

pdil[i] Protein requirement for lactation per cow of category i ($i = 25, ...CC$)

pdim[i] Protein requirement for maintenance per cow of category i ($i = 25, ...CC$)

pdiml Protein requirement per kg milk with given fat and protein percentage

pdims[i] Protein requirement per cow of category i ($i = 25, ..., CC$) for maintenance in the summer feeding period

pdimw[i] Protein requirement per cow of category i ($i = 25, ..., CC$) for maintenance in the winter feeding period

pdipc[i] Total protein requirement for pregnancy per animal of category i ($i = 20, 22, 25, ..., CC$)

pdis[i] Protein requirement per animal of category i ($i = 1, ..., CC + 10$ except $4, 14, 15$) in the summer feeding period

pdis0[i] Protein requirement in the "zeroeth" summer feeding period[25] after weaning per animal of category i ($i = CC + 1, ..., CC + 10$)

[25] This period occurs only if calves are weaned before the end of the pasture period.

pdis1[i] Protein requirement in the 1st summer feeding period after weaning per animal of category i ($i = CC+2, ..., CC+6, CC+8, CC+10$)

pdis2[i] Protein requirement in the 2nd summer feeding period after weaning per animal of category i ($i = CC+2, CC+3, CC+5, CC+6, CC+10$)

pdis3[i] Protein requirement in the 3rd summer feeding after weaning period per animal of category i ($i = CC+3, CC+6$)

pdiscal[i] Total protein requirement from summer feeding per cow of category i ($i = 25, ..., CC$) that had calved in the given reproductive cycle

pdisl[i] Protein available for a calf of category i ($i = 3, 8, 9$) in the summer period from cows' milk

pdisncal[i] Total protein requirement from summer feeding per cow of category i ($i = 25, ..., CC$) that had not calved in the given reproductive cycle

pdisp[i] Protein requirement for pregnancy in the summer period per animal of category i ($i = 20, 22, 25, ..., CC+10$)

pdit Protein requirement per bull in the performance test

pditse Protein requirement per breeding bull from the end of the performance to selling

pdiw[i] Protein requirement per animal of category i ($i = 1, ..., CC+10$ except $4, 14, 15$) in the winter feeding period

pdiw1[i] Protein requirement in the 1st winter feeding period after weaning per animal of category i ($i = CC+2, ..., CC+6, CC+8, CC+10$)

pdiw2[i] Protein requirement in the 2nd winter feeding period after weaning per animal of category i ($i = CC+2, ..., CC+6, CC+8, CC+10$)

pdiw3[i] Protein requirement in the 3rd winter feeding period after weaning per animal of category i ($i = CC+3, CC+5, CC+6$)

pdiw4 Protein requirement in the 4th winter feeding period after weaning per animal of category $CC+6$

pdiwcal[i] Total protein requirement from winter feeding per cow of category i ($i = 25, ..., CC$) that had calved in the given reproductive cycle

pdiwf[i] Protein requirement per female calf from birth to the end of the first feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdiwf2[i] Protein requirement per female calf in the second feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdiwl[i] Protein available per calf of category i ($i = 3, 8, 9$) in the winter period from cows' milk ($i = 25, ..., CC$)

pdiwm[i] Protein requirement per male calf from birth to the end of the first feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdiwm2[i] Protein requirement per male calf in the second feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

pdiwncal[i] Total energy requirement in the winter feeding period per cow of category i ($i = 25, ..., CC$) that had not calved in the given reproductive cycle

pdiwp[i] Protein requirement for pregnancy in the winter feeding period per animal of category i ($i = 20, 22, 25, ..., CC$)

pdry Proportion of cows that are dried with antibiotics

pf[i] Program EWBC: Probability that a conceived cow will bear a dead female calf ($i = 1$) or probability that a born female calf dies within 48 hours after calving ($i = 2$)

pf[j][i] Program EWDC: Probability that a conceived cow will bear a dead female calf ($i = 1$) or probability that a born female calf dies within 48 hours after calving ($i = 2$), ($j = 0$: pure-bred animals, $j = 1$: cross-bred animals)

pff Female calves for fattening as proportion of surplus female calves

Ph[i][j] Program EWBC: Matrix of proportions (in per cent) of heifer carcasses in the ith class of fleshiness and the jth class of fat covering; the elements of the matrix add up to 100

Ph[i][j][k] Program EWDC: Matrix of proportions (in per cent) of heifer carcasses in the ith class of fleshiness and the $j$class of fat covering for pure-bred ($k = 0$) or cross-bred animals ($k = 1$); the elements of the matrix add up to 100

phc1 Heifers culled because of no pregnancy after the 1st mating period after their weaning expressed as proportion of all culled not pregnant heifers

phc2 Heifers culled because of no pregnancy after the 2nd mating period after their weaning expressed as proportion of all culled not pregnant heifers

phc3 Heifers culled because of no pregnancy after the 3rd mating period after their weaning expressed as proportion of all culled not pregnant heifers

Phiscc[i] Cumulative frequency up to the ith class of milk quality due to somatic cell count ($i = 0, ..., nSCC - 2$)

phmat1 Heifers mated in the 1st mating period after their weaning (on the basis of reaching the minimal weight for mating) as proportion of all weaned female calves intended for replacement

phmat2 Heifers mated in the 2nd mating period after their weaning as proportion of all female calves intended for replacement

php1 Heifers pregnant after the 1st mating period after their weaning as proportion of all pregnant heifers

php2 Heifers pregnant after the 2nd mating period after their weaning as proportion of all pregnant heifers

php3 Heifers pregnant after the 3rd mating period after their weaning as proportion of all pregnant heifers

phs Pregnant heifers sold expressed as proportion of surplus female calves

pinmatd[i] Cows having dystocia that were mated in the 1st oestrus within reproductive cycle $i+1$ ($i = 0, ..., LL-2$) as proportion of all mated cows having dystocia in this cycle

pinmatnd[i] Cows without dystocia that were mated in the 1st oestrus within reproductive cycle $i+1$ ($i = 0, ..., LL-2$) as proportion of all mated cows not having dystocia in this cycle

pl Expected milk production level of the herd (1 - lowest, 9 - highest)

pm[i] Program EWBC: Probability that a conceived cow will bear a dead male calf ($i = 1$) or probability that a born male calf dies from calving to 48 hours after calving ($i = 2$)

pm[j][i] Program EWDC: Probability that a conceived cow will bear a dead male calf ($i = 1$) or probability that a born male calf dies from calving to 48 hours after calving ($i = 2$), ($j = 0$: pure-bred animals, $j = 1$: cross-bred animals)

PM[i][j] Gene transmission matrix for gene flow (see Section 2.8)

pncal[i] Calved cows (not pregnant in the previous cycle) in reproductive cycle $i+1$ ($i = 0, ..., LL-2$) as proportion of all cows which entered this cycle

pncalc[i] Calved cows (not pregnant in previous cycle) in category i ($i = 25, ..., CC$) as proportion of all cows in this category

pp[i] Probability within the given reproductive cycle r that a cow which entered this cycle as a pregnant cow belongs to the given stage s (for more details see Section 2.2). Let r ($r = 1, ..., LL$) be the number of the reproductive cycle and s ($s = 1, ..., 6$ for $r < LL$ or $s = 1, .., 4$ for $r = LL$) the number of the stage, then $i = 6(r+3) + s$ and

$$\sum_{i=6(r+3)+1}^{i=6(r+3)+S} pp[i] = 1$$

for all r and $S = 6$ (for $r < LL$) or $S = 4$ (for $r = LL$). The variable is defined for $i = 25, ..., CC$

pr[i] Price per kg live weight for living animals or per kg slaughter weight for fattened animals of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

prai Price per portion of semen for AI

praib Price per portion of semen for AI from beef bulls

praid Price per portion of semen for AI from dairy bulls

prair Price per re-insemination

prairb Price per re-insemination from beef bulls

praird Price per re-insemination from dairy bulls

pranim[i] Program EWDC: Price per animal ($i = 8, 9, 10, 23, 24, CC+8, CC+9, CC+10, CC+23, CC+24$)

pras[i] Price per kg fresh matter of the feeding ration in the fattening period after extensive fattening on pasture for animals of category i ($i = 5, 6, 12, 13, 16, 17$)

prb Price per kg slaughter weight of bulls in the base class of fleshiness and fat covering

Prb[i][j] Matrix of coefficients of carcass prices for bulls in the ith class of fleshiness and jth class of fat covering relative to the price in the base class of fleshiness and fat covering

prbb Price per breeding bull purchased for natural mating

prbbcull Price per kg carcass weight of old breeding bulls

prbbsel Price per performance tested and selected breeding bull

prc Price per kg slaughter weight of cows in the base class for fleshiness and fat covering

Prc[i][j] Matrix of coefficients of carcass prices for cows in the ith class of fleshiness and jth class of fat covering relative to the price in the base class of fleshiness and fat covering

prcs Price per kg slaughter weight of castrates in the base class for fleshiness and fat covering

Prcs[i][j] Matrix of coefficients of carcass prices for castrates in the ith class of fleshiness and jth class of fat covering relative to the price in the base class of fleshiness and fat covering

prdg Price per kg dung

preg2nmc[i] Cows conceived in the 2nd oestrus in the mating period as proportion of all pregnant cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

preg2nmh Heifers conceived in the 2nd oestrus in the mating period as proportion of all pregnant heifers in this mating period

preg3nmc[i] Cows conceived in the 3rd oestrus in the mating period as proportion of all pregnant cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

preg3nmh Heifers conceived in the 3rd oestrus in the mating period as proportion of all pregnant heifers in this mating period

pregaic[i] Cows conceived in the 1st oestrus in the mating period as proportion of all pregnant cows in reproductive cycle $i + 1$ ($i = 0, ..., LL - 2$)

pregaih Heifers conceived in the 1st oestrus in the mating period as proportion of all pregnant heifers in this mating period

prf[i] Program EWBC: Price per kg fresh matter of the feeding ration in intensive fattening for animals of category i ($i = 4, 5, 6, 12, 13, 14, 15, 16, 17$), Program EWDC: Price per kg fresh matter of the feeding ration for animals of category i ($i = 1, ...CT$)

prf10 Price per kg fresh matter of feed ration for breeding bulls from the end of the rearing period of calves till selling

prf2[i] Price per kg fresh matter of the feeding ration for reared calves of category i ($i = 3, 8, 9, 10, CC + 3, CC + 8, CC + 9, CC + 10$) in the second feeding period

prfwf[i] Price per kg fresh matter of the feeding ration for female calves in the first feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

prfwf2[i] Price per kg fresh matter of the feeding ration for female calves in the second feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

prfwm[i] Price per kg fresh matter for male calves in the first feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

prfwm2[i] Price per kg fresh matter of the feeding ration for male calves in the second feeding period in rearing calves ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

prh Price per kg slaughter weight for heifers in the base class for fleshiness and fat covering

Prh[i][j] Matrix of coefficients of carcass prices for heifers in the ith class of fleshiness and jth class of fat covering relative to the price of the base class of fleshiness and fat covering

pricedry Price per dose of drug for drying cows

priceherd Value of herdsman's time in monetary units per hour

pricevet Average charge for veterinary service

prm[i] Price per kg minerals for animals of category i ($i = 1, ..., CC$ except $4, 14, 15$)

prmilk Price per kg milk of given fat and protein content and given somatic cell count

prmilkb Basic milk price per kg milk, input parameter

prmilkf[i] Bonus or penalty for fat content per kg milk in the ith class of fat content ($i = 0, ..., nfat$)

prmilkfp Milk price corrected for fat and protein content and not yet corrected for milk quality classes (per kg milk)

prmilkp[i] Bonus or penalty for protein content per kg milk in the ith class of protein content ($i = 0, ..., nprot$)

prnphse Program EWBC: Price per kg live weight of not pregnant breeding heifers

prodsys Production system (takes values 1 to 4, see Section 4.1.1.1)

prodsys2 In program EWDC: production system (takes values 1 to 3, see Section 4.1.1.1) for which the data for the file FROM1_3.TXT were calculated

profitab Profitability without governmental subsidies

profitabd Profitability including governmental subsidies

prot	Protein content in milk
prot305ave	305d protein yield (kg)
protkg	Protein yield (kg) produced over the whole lactation
prphse	Program EWBC: Price per kg live weight of pregnant breeding heifers at selling
prrep	Price per kg live weight of pregnant breeding heifers purchased for replacement
prs[i]	Price per kg fresh matter of summer feed ration for category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)
prscc	Temporary variable for calculating the milk price
prSCC[i]	Vector of basic prices per kg milk in quality class i ($i = 1, ...NSCC$)
prst	Price per kg straw
prt	Price per kg fresh matter of feed ration for breeding bulls in the performance test
prtb	Price per kg fresh matter of feed ration for breeding bulls before the performance test
prtse	Price per kg fresh matter of feed ration for breeding bulls from the end of the performance test to selling
prw[i]	Price per kg fresh matter of winter feed ration for animals of category i ($i = 1, ..., CC$ except $i = 4, 14, 15$)
prwt	Price per l water
pSCC[i]	Program EWDC: Vector of proportions of sold milk in quality class i ($i = 1, ..., nSCC$)
psum	Number of progeny per cow and reproductive cycle
p_tot[i]	Number of progeny of category i ($i = 1, ..., 24$) (Sum of pure-bred and cross-bred progeny)
pydry	proportion of cows that are dried with antibiotics per cow and year
qc[i]	Discounting coefficient for cost for category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)
qr[i]	Discounting coefficient for revenues for category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)
rev[i]	Revenues per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)
revc	Total revenues per cow and year (summed *only* over all *cow categories*)
revcullc	Revenues from culled cows summed over all cow categories, per cow and year
revmilk[i]	Revenues from milk per cow of category i ($i = 25, ...CC$)
revmilkc	Revenues from milk from all cow categories per cow and year

rf[i][j] Coefficients for the regression of the milk price on the milk fat content. $i = 0$: intercept, $i = 1$: linear regression coefficient; j ($j = 0, ..., nfat$) refers to the class for fat content.

rp[i][j] Coefficients for the regression of the milk price on the milk protein content. $i = 0$: intercept, $i = 1$: linear regression coefficient; j ($j = 0, ..., nprot$) refers to the class for protein content.

sfrp Program EWBC: Heifers selected on health and exterior before mating as proportion of reared heifers

sfrp[i] Program EWDC: Heifers selected on health and exterior before mating as proportion of reared heifers ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

sigmafat Phenotypic standard deviation for milk fat content

sigmaprot Phenotypic standard deviation for milk protein content

sigmaSCS Phenotypic standard deviation of somatic cell score in the dairy cow population

sigmawh Phenotypic standard deviation of the weight of heifers at first mating (at an age of about 1 year)

sl_1[i] Average amount of milk in kg produced per cow in the summer period in reproductive cycle 1 available for calves of category i ($i = 3, 8, 9$)

sl_2[i] Average amount of milk in kg produced per cow in the summer period in reproductive cycle 2 available for calves of category i ($i = 3, 8, 9$)

sl_3[i] Average amount of milk in kg produced per cow in the summer period in reproductive cycle 3 available for calves of category i ($i = 3, 8, 9$)

sl[i] Average amount of milk in kg produced per cow in the summer period (according to the age structure of the cows in the herd) available for calves of category i ($i = 3, 8, 9$)

sl2 Sum of elements of vector **l2**

sp[i] Service period of cows of category i ($i = 25, ...CC - 3$)

startbt Starting date for the performance test of bulls (only in Production System 1)

stcd[i] Still born calves after dystocia as proportion of cows having dystocia in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

stce[i] Still born calves after easy calving as proportion of cows having easy calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

stdm Genetic standard deviation for milk production

straw[i] Program EWBC: Daily amount of straw per animal of category i ($i = 1, ..., CC$) during the winter housing period. Program EWDC: Daily amount of straw per animal of category i ($i = 1, ..., CT$)

straw10 Amount of straw per breeding bull per day

strawbb Daily amount of straw per breeding bull in the herd during the winter housing period

strawfi Daily amount of straw per animal in intensive fattening

strawfx Daily amount of straw per animal in extensive fattening during the winter housing period

strawwf[i] Daily amount of straw per female calve in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

strawwm[i] Daily amount of straw per male calve in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

suml1 Sum of elements of vector **l1**

T Number of cow categories + 1

t[i][j] Elements of the transmission matrix for the calculation of the herd structure ($i, j = 1, ..., TT$)

tc[i] Length of the time period (in years) from calving to the time when the costs in category i occur (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

tconh Total conception rate of heifers in a mating period

tconh3 Program EWDC: Total conception rate of heifers in System 3

Tcost Total cost per cow entering the reproductive cycle (per cow and year)

tech1 Housing technology in fattening (1: free technology, 2: bind technology, 3: pasture, see Section 4.1.1.4)

tech2 Housing technology in the cow herd (1: free technology, 2: bind technology, 3: pasture, see Section 4.1.1.4)

thfat[i] Threshold values for milk fat content in the milk paying system ($i = 0, ..., nfat - 1$)

thprot[i] Threshold values for milk protein content in the milk paying system ($i = 0, ..., nprot - 1$)

totcal[i] Proportion of pure-bred ($i = 0$) and cross-bred ($i = 1$) calvings in the herd

Tprof Total profit per cow entering the reproductive cycle (per cow and year)

Tprofh Needed for the calculation of economic weights

Tprofl Needed for the calculation of economic weights

Tprofm In the calculation of economic weights: keeps the value of the total profit $Tprof$

tr[i] Length of the time period (in years) from calving to the time when the revenues in category i occur (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)

trait Number of the trait (see Section A.2 on page 98)

Trev Total revenues per cow entering the reproductive cycle (per cow and year)

tSCC[i]	Upper limits for somatic cell count in milk quality class i ($i = 0, ..., nSCC-2$) (the 1st class being the best one)
tSCS[i]	Upper limits for somatic cell score in milk quality class i ($i = 0, ..., nSCC-2$) (the 1st class being the best one)
TT	Dimension of quadratic matrix t[i][j], $TT = 6(LL-1)+4$
tvh	Needed for the calculation of economic weights
tvl	Needed for the calculation of economic weights
tvm	Needed for the calculation of economic weights
u	Discount rate
utifemp	Utilisation of pure-bred female calves which are not needed for replacement (1: selling of surplus reared female calves outside the systems, 2: fattening of surplus reared female calves, 3: selling of surplus breeding heifers before mating, 4: selling of surplus pregnant breeding heifers)
utifemcr	Utilisation of cross-bred female calves (1: selling of reared calves outside the system, 2: fattening of reared calves, 3: selling [transferring] of cross-bred heifers to cow-calf Production System 3, 4: combination of fattening and selling of cross-bred female calves)
varmilk	Variable costs per kg milk for increasing milk yield above average (labour, machine, cooling, energy etc.)
vetdys[j]	Veterinary cost connected with calving difficulty score j+1 ($j = 0, ..., DD-1$)
w[i]	Program EWBC: Mature weight of bulls (= mwb, defined only for $i = 10$)
w1conf	Weight of female calves at first weighing
w1conm	Weight of male calves at first weighing
w2conf	Weight of female calves at second weighing
w2conm	Weight of male calves at second weighing
w3conf	Weight of female calves at third weighing
w3conm	Weight of male calves at third weighing
wat[i]	Daily amount of water per animal of category i (Program EWBC: $i = 1, ..., CC$, Program EWDC: $i = 1, ..., CT$)
wat10	Amount of water per breeding bull per day
watwf[i]	Daily amount of water per female calf in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
watwm[i]	Daily amount of water per male calf in the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)
wbbse	Weight of breeding bulls at purchase for natural mating
wbbst	Average weight of breeding bulls at the start of the performance test

wbbt Average weight of breeding bulls at the end of the performance test

wbfat Program EWBC: Live weight of bulls at slaughter (at the end of fattening)

wbfat[i] Program EWDC: Live weight of bulls at slaughter (at the end of fattening; $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wbfatb Program EWDC: Live weight of pure-bred beef bulls at slaughter at the end of fattening

wcacal[i] Average weight of cows after calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

wcc[i] Average weight of cows culled within reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$) for health problem excluding dystocia

wccal[i] Average weight of cows at calving in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

wccw[i] Average weight of cows culled after calf weaning due to no pregnancy in reproductive cycle $i + 1$ ($i = 0, ..., LL - 1$)

wcd[i] Average weight of cows died within reproductive cycle $i+1$ ($i = 0, ..., LL-1$)

wcdys[i] Average weight of cows culled due to dystocia in reproductive cycle $i+1$ ($i = 0, ..., LL - 1$)

wcfat Program EWBC: Live weight of castrates at slaughter (at the end of fattening)

wcfat[i] Program EWDC: Live weight of castrates at slaughter (at the end of fattening; $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wcfatb Program EWDC: Live weight of beef castrates at slaughter (at the end of fattening)

wcwsc Program EWBC: Average weight of castrates culled in the period from weaning to the end of fattening before reaching the required slaughter weight

wcwsc[i] Program EWDC: Average weight of castrates culled in the period from the end of the rearing period to the end of fattening before reaching the required slaughter weight ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wcwsf Program EWBC: Average weight of females culled in the period from weaning to the end of fattening before reaching the required slaughter weight

wcwsf[i] Program EWDC: Average weight of females culled in the period from the end of the rearing period to the end of fattening before reaching the required slaughter weight ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wcwsm Program EWBC: Average weight of males culled in the period from weaning to the end of fattening before reaching the required slaughter weight

wcwsm[i] Program EWDC: Average weight of males culled in the period from the end of the rearing period to the end of fattening before reaching the required slaughter weight ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wcxfat Live weight of castrates at slaughter in extensive fattening

wcxs Weight of castrates in extensive fattening at the end of the pasture period

wcxw Weight of castrates in extensive fattening at the end of the winter period after weaning

wdcwf Program EWBC: Average weight of female calves died from 2 days of age to weaning

wdcwf[i] Program EWDC: Average weight of female calves died from 2 days of age to the end of the rearing period ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wdcwm Program EWBC: Average weight of male calves died from 2 days of age to weaning

wdwsc Program EWBC: Average weight of castrates died in the period from weaning to the end of fattening

wdwsc[i] Program EWDC: Average weight of castrates died from the end of the rearing period to the end of fattening ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wdwsf Program EWBC: Average weight of heifers died in the period from weaning to the end of fattening

wdwsf[i] Program EWDC: Average weight of heifers died from the end of the rearing period to the end of fattening ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wdwsm Program EWBC: Average weight of bulls died in the period from weaning to the end of fattening

wdwsm[i] Program EWDC: Average weight of bulls died from the end of the rearing period to the end of fattening ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

wfrep Weight of females for replacement at purchase

wfxs Weight of heifers in extensive fattening at the end of the pasture period

wfxw Weight of heifers in extensive fattening at the end of the winter period

wh1cal Program EWBC: Weight of heifers after the 1st calving for heifers conceived in their 1st mating period after their weaning. Program EWDC: Weight of heifers after their 1st calving

wh2cal Weight of heifers after their 1st calving for heifers mated in their 2nd mating period after weaning

wh3cal Weight of heifers after their 1st calving for heifers conceived in their 3rd mating period after weaning

whcal Weight of heifers after their 1st calving (average from heifers conceived in their 1st, 2nd and 3rd mating period after weaning)

whcmat Program EWBC: Average weight of heifers culled after the 1st, 2nd and 3rd mating periods after weaning because of no pregnancy. Program EWDC: Average weight of heifers culled after the maximal number of inseminations because of no pregnancy

whcmat1 Average weight of heifers culled after the 1st mating period after their weaning because of no pregnancy

whcmat2 Average weight of heifers culled after the 2nd mating period after their weaning because of no pregnancy

whcmat3 Average weight of heifers culled after the 3rd mating period after their weaning because of no pregnancy

whdmh Average weight of heifers died from weaning (or from the end of the rearing period of calves in System 4) to entering the herd

whfat Program EWBC: Live weight of heifers at slaughter (at the end of fattening)

whfat[i] Program EWDC: Live weight of heifers at slaughter (at the end of fattening; $i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

whfatb Program EWDC: Live weight of pure-bred beef heifers at slaughter at the end of fattening

whmat Program EWBC: Weight of heifers at mating averaged over all three mating periods

whmat1 Program EWBC: Average weight of heifers at mating for heifers mated in their 1st mating period after weaning

whmat1[i] Program EWDC: Average weight of heifers at their 1st insemination ($i = 0$: pure-bred animals, $i = 1$: cross-bred animals)

whmat2 Average weight at mating for heifers mated in their 2nd mating period after weaning

whmat3 Average weight at mating for heifers mated in their 3rd mating period after weaning

whmin Minimal live weight of heifers for mating

whxfat Live weight of heifers at slaughter in extensive fattening

wl_1[i] Average amount of milk in kg produced during the winter period per cow in reproductive cycle 1 available for calves of category i ($i = 3, 8, 9$)

wl_2[i] Average amount of milk in kg produced during the winter period per cow in reproductive cycle 2 available for calves of category i ($i = 3, 8, 9$)

wl_3[i] Average amount of milk in kg produced during the winter period per cow in reproductive cycle 3 available for calves of category i ($i = 3, 8, 9$)

wl[i] Average amount of milk in kg produced during the winter period per cow (according to the age structure of the cows in the herd) available for calves of category i ($i = 3, 8, 9$)

wnphse Program EWBC: Weight of not pregnant breeding heifers at selling

wphse Program EWBC: Weight of pregnant breeding heifers at selling

wpreg Weight gain for pregnancy = loss of cow weight after calving averaged over reproductive cycles 1 to LL

ws0[i] Weight of animals of category i ($i = CC+1, \ldots, CC+10$) at the end of the "zeroeth" summer feeding period[26] after their weaning

ws1[i] Weight of animals of category i ($i = CC+2, CC+4, CC+8$) at the end of the 1st summer feeding period after their weaning

ws2[i] Weight of animals of category i ($i = CC+3, CC+5$) at the end of the 2nd summer feeding period after their weaning

ws3 Weight of animals of category $CC+6$ at the end of the 3rd summer feeding period after their weaning

ww[i] Program EWBC: Live weight of animals of category i ($i = 3, 8, 9, 25, ..., CC$) at the end of the winter feeding period, Program EWDC: Average live weight of animals of category i

ww1[i] Weight of animals of category i ($i = CC+1, CC+2, CC+9$) at the end of the 1st winter feeding period after their weaning

ww2[i] Weight of animals of category i ($i = CC+2, CC+3, CC+10$) at the end of the 2nd winter feeding period after their weaning

ww3[i] Weight of animals of category i ($i = CC+3, CC+6$) at the end of the 3rd winter feeding period after their weaning

wwbse Live weight of male breeding calves at the start of the performance test

wwf Program EWBC: Weaning weight of female calves

wwf[i] Program EWDC: Weight of female calves at the end of the rearing period

wwm Program EWBC: Weaning weight of male calves

wwm[i] Program EWDC: Weight of male calves at the end of the rearing period

ymi Average mastitis incidence rate per cow and year (number of clinical mastitis cases per cow and year averaged over all lactations)

zr Number of run when calculating economic weights

zz Integer variable for numbering subsections in the output file TEXT_OUT.TXT (see Section 4.4)

zzdmi[i][j] Needed for the calculation of economic weights (keeps the values of $dmi[i][j]$ during the calculation of the economic weight for mastitis incidence, of the same dimension as $dmi[i][j]$)

zzircmy[i] Needed for the calculation of economic weights (keeps the values of $ircmy[i]$ during the calculation of the economic weight for mastitis incidence, of the same dimension as $ircmy[i]$)

zzlosc[i] Needed for the calculation of economic weights, $i = 1, ..., 50$

zzmilksum[i] Needed for the calculation of economic weights, keeps the original values of milksum[i]

[26] This period occurs only if calves are weaned before the end of the pasture period.

Appendix B

Changes in the program EWBC since Version 1.0.22

B.1 Changes in May 2004

- Output file FROM1_3.TXT in Program EWBC was added (see Section 5.1.3 on page 94).

B.2 Changes in January 2005

- Special cases with zero trait values were taken into account when calculating the economic values (see Section 2.7.1).
- The option way of calculating feeding cost from the parameter file PARA.TXT (see Section 4.1.2) which was of no effect until recently will now work correctly.
- The economic values for the categorical traits 14 to 25 (see Numbering of traits, Appendix A.2 on page 98) will be calculated with the opposite sign as before. This change was made to put the printed values in agreement with the description of their calculation in Section 2.7.3 and to unify the calculation of economic weights. From now on, the economic weight will be always defined as the change in the total profit when increasing the trait value. Therefore the economic weights of traits where a decrease will be of a positive economic effect will have a negative sign.
- The input variable *dotcows* (Governmental subsidies per slaughter cow) was added in input file INPUT03.TXT.
- The new variable *ncows* (see Appendix A.3) was added.
- The profitability is newly calculated with and without subsidies and printed in the results file.
- The equation for the calculation of the average date of calving for cows in the herd (*davcalc*) was corrected. The change will be only of small impact on the results.
- The calculation of total cost for a breeding bull for natural mating in the herd from purchase to slaughter was corrected. The costs were decreased by the revenues from the slaughter animal.

- The variable *anphse* (average age of not pregnant breeding heifers at selling) is not calculated in the program, but added as input parameter to the file INPUT13.TXT.
- The variable *aih* (heifers mated in their 1st oestrus as proportion of mated heifers) which was missing in input file INPUT14.TXT was added to this file.
- The variables *prrep*, *prnphse* and *prphse* (price of pregnant breeding heifers purchased for replacement, price of not pregnant breeding heifers and price of pregnant breeding heifers at selling) which were defined per animal were redefined as prices per kg live weight.
- The variable *prbbcull* (price per kg carcass weight of old breeding bulls) was added to input file INPUT04.TXT.
- The variable *prbbsel* (price per breeding bull sold after test and selection) was added to input file INPUT05.TXT.
- The meaning of the variable *prbb* was changed to price per breeding bull purchased for natural mating (input file INPUT04.TXT).
- The variable $kmcwhmin = whmin/mcw$ was added in the program.
- Further cost components were calculated in the program and printed to the result file. These components are: *costcowy*, *costcw*, *costcwf*, *costcwm*, *costcwfkg*, *costcwmkg*, *costfatb*, *costfatbkg*, *costfatc*, *costfatckg*, *costfath*, *costfathkg*, *costhnpr*, *costhnprkg*, *costhpr*, *costhprkg*, *costvetc*, *costhc*, *costoc*, *costfixc*, *costfc*, *costc*. For their definition see List of variables in Appendix A.3.
- The calculation of the variables $avelifecc$ and $avelifecy$ was corrected. The meaning of the variable $avelifecc$ was changed.

B.3 Changes in February 2005

- The variable *agehcal* which was the same as *agecal* was omitted and replaced by *agecal*.
- The number of reproductive cycles which was originally fixed to 10 is now variable and can be chosen by the user (values from 4 to 20 are allowed, low values might not work in several cases from the reason that there were not enough replacement heifers). The number of reproductive cycles (variable LL) was added as input parameter to the parameter file PARA.TXT. This had consequences for the dimension of vectors read from input files INPUT02.TXT and INPUT26.TXT. Several parameters in the program (T, C and G) are now the upper limit of the dimension of the appropriate vectors or matrices. The current values of these parameters (TT, CC and GG) are calculated from the current value of LL. The number of reproductive cycles was added as output parameter to the file FROM1_3.TXT.
- The expression of the economic values $ew0[i]$ was changed to be identical with the expression of the values $ew[i]$ (Originally, $ew[i]$ was expressed per change of the trait by 0.01 class or 10 g or 1%, whereas $ew0[i]$ was always expressed per unit of the trait, i.e. per class etc.). This has absolutely no consequences for the users of the program, as only the values $ew[i]$ are printed to the results file. All these values remained unchanged.

- An error in the calculation of the gene flow was corrected. The error had only impact on Systems 2 and 3.

B.4 Changes from August to November 2005

- The input parameter *quota* was omitted from the parameter file PARA.TXT because this parameter is not used in the calculations.
- The units of the marginal economic values for traits 6 to 9 (average daily gain of calves from birth to 1st weighing, average daily gain of calves from the 1st to 2nd weighing, average daily gain of calves from the 2nd to 3rd weighing and average daily gain in the fattening period to constant slaughter weight) were changed from MU[1] per 10 g/d, cow and year to MU per g/d, cow and year.
- The marginal economic values for traits 14 to 17 (mean class of fleshiness for cows, bulls, heifers and castrates, respectively) and for traits 19 to 22 (mean class of fat covering for cows, bulls, heifers and castrates, respectively) are now expressed in the same way as the cumulative traits 18 and 23 (mean class of fleshiness or fat covering, respectively, for all categories together), e.g. per change of the mean class by 0.01.
- The marginal economic values for traits 24 and 25 (average score for calving performance for female or male calves, respectively) are now expressed in the same way as the cumulative trait 1 (average score for calving performance for male and female calves together), e.g. per change of the mean calving score by 0.01.
- The parameter NT was changed from 31 to its correct value 30 (number of traits increased by 1). This is of no consequence to the results, just unnecessary calculations are omitted.
- In all input files was the abbreviation Kc (Czech crowns) replaced by the more general term MU (monetary unit).
- Improvements in the text of all input files were made. This is of no effect to the program itself.

B.5 Changes from December 2008 to January 2009 (Version 2.1.1)

- The main change in the program is that calving is now possible at any time outside of the pasture period.
- The calculation of the variables *ndaycw* and *wh*1*cal* was modified.
- The last input in INPUT13.TXT (*anphse*) was replaced by four variables: *anphse*1, *anphse*2, *nphsold*1 and *nphsold*2.*anphse* will be calculated from these four variables in the program.
- In the program, two new variables (*aphse*1 and *aphse*2) were introduced.
- The structure of the output file CHECK was changed. All variables are now printed in only one alphabetic list.

[1] monetary unit

- The parameter "Utilisation of female calves which are not needed for replacement" ($utifem$) was found to be unnecessary and misleading and was therefore omitted from the program. This has no impact on the results.
- Five new variables were introduced: $adgs0[i]$, $ds0[i]$, $nes0[i]$, $pdis0[i]$ and $ws0[i]$ where i is the category of animals.

B.6 Changes from October 2009 to January 2010 (Version 2.1.2)

- The values of some variables which were printed as -0.00000 are now printed without the minus sign.

Appendix C

Changes in the program EWDC since Version 1.0.18 (version 2.0.18 of the package ECOWEIGHT)

C.1 Changes in May 2006

- The part of the program concerning the calculation of the milk price was rewritten. For details see Section 2.5.1.2 which was also rewritten on the basis of the changes in the program. In the parameter file PARAD.TXT, the option for the calculation of the milk price was added (variable *milkprice*). The five options are explained in Paragraph 4.1.1.14.
- In the input file INPUT28.TXT, the new input parameter basic milk price (*prmilkb*) was introduced. Several input parameters connected with somatic cell count or somatic cell score (mean of somatic cell score $mSCS$, phenotypic standard deviation of somatic cell score $sigmaSCS$, number of milk quality classes according to somatic cell content $nSCC$, upper limits for somatic cell count in the individual milk quality classes $tSCC[i]$) were moved from INPUT23.TXT to INPUT28.TXT.
- The input parameter "vector of basic prices per kg milk in quality class i" ($prSCC[i]$) was moved from input file INPUT07.TXT to INPUT28.TXT.
- In input file INPUT11.TXT, a new input parameter (interval between two subsequent inseminations *inint*) was added.
- Two typing errors in equation (2.21) were corrected in the Manual.

C.2 Changes in January 2007

An error was detected in printing out the economic weight for mastitis incidence. The program printed a value ten times greater than it should be. The error was corrected.

C.3 Changes in June and July 2007

- A new parameter "Crossing in the herd" was added to the parameter file PARAD.TXT.
- A bug was fixed were an array exceeded its limit.
- The calculation of some missing quantities for category 89 ($CC+7$) was added.
- Changes were made in the algorithm for printing out the results in the results file. The output has become more selective omitting unnecessary data.
- The number of classes for calving performance which was fixed to 4 is now variable and can take values from 2 to 6.
- The structure of input file INPUT07.TXT was changed. The change concerns the last part of the file where input parameters for calving scores were sorted by the type of breeding - first the parameters for purebreeding are given and then the parameters for crossbreeding are listed. The maximal number of calving scores has changed from 4 to 6. Leave all the lines in the input file, even if they are not read. The values for the classes of calving scores not occupied are just ignored.
- The structure of input file INPUT11.TXT was changed. At the beginning, the variable 'number of classes for calving performance' was added. Instead of four inputs for 'Veterinary cost connected with calving score x' and 'Stockman hours connected with calving score x' there are now six inputs.

C.4 Changes in October 2007

The aim of the changes carried out in October 2007 in the program EWDC was to include the option of selling male calves in the dairy system a few days after birth. Furthermore, the option of paying per live animal was added for calves and dystocia can be defined by the user.

- In input file INPUT21.TXT, several new parameters were included: price for female and male calves per animal (until recently, only paying per kg live weight was allowed), cost for removing and rendering dead calves.
- The definitions of the parameters $mxmc[i]$ and $mtest[i]$ were changed to "Proportion of male calves alive at 48 hours after birth that are determined for export (selling outside of the evaluated production system)" and "Proportion of male calves alive at 48 hours after birth that are sold as breeding males (e.g. to test stations or AI stations)". Both parameters are in input file INPUT15.TXT.
- In input file INPUT11.TXT, the new input parameter $dyscl$ was included. The parameter is the number of the lowest score for calving performance which is considered to be dystocia.
- In input file INPUT07.TXT, an additional comment was added which does in no way change the functionality of the file.
- The new option of selling male calves made it necessary to change the way the costs for categories 3 and $CC+3$ were calculated; furthermore, the time when the costs for these categories occur had to be changed.
- The variables $Nmcw[i]$ and $wdcwm[i]$ were deleted in the program.

- The file TEXTD_OUT.TXT was changed to improve the output of results and to adopt it to the new features in the program.

C.5 Changes in November 2007

The maximal number of reproductive cycles which was originally fixed to 10 was made variable and can now be in the range from 4 to 15. Changing the number of reproductive cycles has consequences especially in input files INPUT07.TXT, INPUT27.TXT and INPUT29.TXT where care must be taken in all input parameters which depend on the number of reproductive cycles.

C.6 Changes in December 2007

- In input file INPUT21.TXT, the price of male breeding calves and breeding heifers which has been given either per kg live weight or per animal until recently may now be expressed both per kg live weight or per animal.
- In the file TEXTD_OUT.TXT in subsection 3.1. the reference unit "per cow and year" was corrected to "per cow and reproductive cycle".
- The variables $prnphse[i]$ and $prphse[i]$ were replaced by $pr[*]$ where $*$ stands for the corresponding categories of animals. Similarly, the variables $wnphse[j]$ and $wphse[j]$ were replaced by $ww[23+j\times CC]$ and $ww[24+j\times CC]$, $anphse[j]$ and $aphse[j]$ were replaced by $age[23+j\times CC]$ and $age[24+j\times CC]$. The variable $wwbse$ was changed to $ww[10]$ and $agebse[j]$ was changed to $age[10+j\times CC]$. All these changes are of absolutely no effect on the calculation, it's just a cleaning up of unnecessary variables.
- A new input file (INPUT12.TXT) was introduced. This input file is necessary in production systems where reared breeding male calves are kept to higher age at farms, that means stay at farms after the rearing period of calves till their selling to AI stations. As a consequence, the calculation of the costs for category 10 was generalized to inlcude this situation.
- A bug in the calculation of costs for categories 23 and $23+CC$ was eliminated. A correction was made in calculation of costs for categories 3 and $3+CC$ which is only of negligible impact on the results.

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