Economic Values of Traits for Dairy Cattle Improvement Estimated Using Field Recorded Data

by

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Abstract

M.Sc. Annie St-Onge Animal Science

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The objective of this study was to compute economic values of traits for dairy cattle improvement using an empirical approach. Field recorded data were obtained from the *Programme d'Analyse des Troupeaux Laitiers du Québec* (PATLQ) and genetic evaluation data were obtained from the Canadian Dairy Network (CDN). After the editing procedure, the data set consisted of 195,001 lifetime records of Holstein, Ayrshire, Jersey, Brown Swiss and Canadienne cows which calved for the first time between January 1980 and December 1994.

Different profitability measurements were computed and used as the dependent variables in covariance model to compute different sets of economic values. Since the majority of cows produced 5 lactations or less, results obtained by using lifetime profits and profits until the end of the fifth lactation are similar. A kilogram genetic increase in fat production had higher economic values than the same increase in milk production in all breeds. A unit genetic increase in conformation had the highest positive impact on profit while a same increase in capacity had a negative impact on profit. Results obtained by using lifetime profit adjusted for the opportunity cost of postponed replacement showed that this adjustement reduced the influence of type traits on profit. Finally, profits of first lactations were used to study consequences of changes in pricing systems occurred in Quebec in August 1992. Economic values attached to protein production changed drastically. A kilogram genetic increase in protein production had negative economic values in the 80's and positive economic values after August 1992.

Résumé

M.Sc. Annie St-Onge Sciences Animales

Valeurs Économiques des Caractères de Sélection Chez les Bovins Laitiers Estimées en utilisant des Données Récoltées à la Ferme

L'objectif de cette étude était de calculer de manière empirique les valeurs économiques des caractères de selection chez les bovins laitiers. Les données de champ utilisées ont été obtenues du Programme d'Analyse des Troupeaux Laitiers du Québec (PATLQ) et les données génétiques, du Réseau Laitier Canadien (RLC). Après le nettoyage des données, la base de données finale contenait de l'information sur la vie productive complète de 195 001 vaches laitières de race Holstein, Ayrshire, Jersey, Suisse brune ou Canadienne qui ont toutes vêlées pour une première fois entre janvier 1980 et décembre 1994.

Différentes mesures de profits ont été calculées et utilisées comme la variable dépendante d'une analyse de covariance afin d'obtenir différentes séries de valeurs économiques. Comme la majorité des vaches laitières produisent cinq lactations ou moins, les résultats obtenus en utilisant les mesures de profit à vie et de profit jusqu'à la fin de la cinquième lactation ont été similaire. Pour toutes les races, l'augmentation d'un kilogramme dans la valeur d'élevage de la production de gras a eu de valeurs économiques supérieures à une même augmention dans la valeur d'élevage de la production de lait. L'augmentation d'une unité dans la valeur d'élevage du trait appelé conformation a eu le plus grand impact positif sur le profit, alors qu'une même augmentation dans la valeur d'élevage du trait appelé capacité a eu un impact négatif sur le profit. Les résultats obtenus en utilisant le profit ajusté pour le cout d'opportunité associé au retardement du replacement de l'animal a montré que cette ajustement réduisait l'influence des traits de conformation sur le profit.

Finalement, le profit obtenu pour la première lactation des vaches a été utilisé pour étudier les conséquences des changements survenus dans le système de paiement du lait survenus en août 1992. Les valeurs économiques associées à la production de protéine ont tous changé drastiquement. Une augmentation d'un kilogramme dans la valeur d'élevage pour

la production de protéine avait une valeur économique négative dans les années 80 pour devenir positive après le mois d'août 1992.

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I. Introduction

Geneticists. as breeders. have important decisions to take when the time arrives to choose parents of the next generation. They want to improve animal populations and obtain from selected parents offspring which are genetically and consequently phenotypically better generation after generation. However. how can they find which animals are the best? On what should they base their choices? How do they decide which individuals become parents?

The animal's phenotype is the combination of its genotype and the environment's effects where the animal lives. What we can measure is the phenotype; however. what the animal will give or transmit to its offspring is a random half sample of its genotype. For many years. mathematicians and statisticians have helped breeders to combine records of measurements they take on animals and find the best way to achieve selection. Selection is the process that determines which individuals become parents. how many offspring they may produce. and how long they remain in the breeding population (Bourdon. 1997). Selecting an animal for only one trait is simple: we only have to choose the best animals according to this trait. However. more than one trait usually affects the value of an animal. Moreover, these traits are not all equally important or all independent of each other. Multi-trait selection is thus more complicated than single-trait selection. Several methods have been used to achieve the most efficient multi-trait selection. Three main general forms have obtained most consideration: tandem selection. selection using independent culling levels. and selection using a selection index.

Tandem selection is selection for one trait at a time until it is improved to a certain level. then for another. It is, in its pure form. just single-trait selection. However, the idea of a selection target, which is the level of breeding value considered optimal, and absent from single-trait selection, is incorporated in this method. For example, a breeder who wants to select dairy cows based on milk and protein yields might select for milk yield until the selection target for the first trait (milk yield) is reached, and then switch to selection for protein yield.

The method of selection using independent culling levels is to select for all the traits simultaneously, but independently rejecting all individuals that are below a certain level of merit established beforehand for each trait. For example, we might decide that dairy cows selected for their milk and protein yields cannot have a high milk production and a low protein yield, both traits must be above a certain standard depending on what is desirable for these traits. In figure 1, cows selected (■) must have an estimated breeding value (EBV) for milk yield higher than +10 and an EBV for protein yield higher than +5. Since animals are rejected when they fail to meet even one standard regardless of the merit for the other traits, this method is more appropriate when there is a clear distinction between what is acceptable and

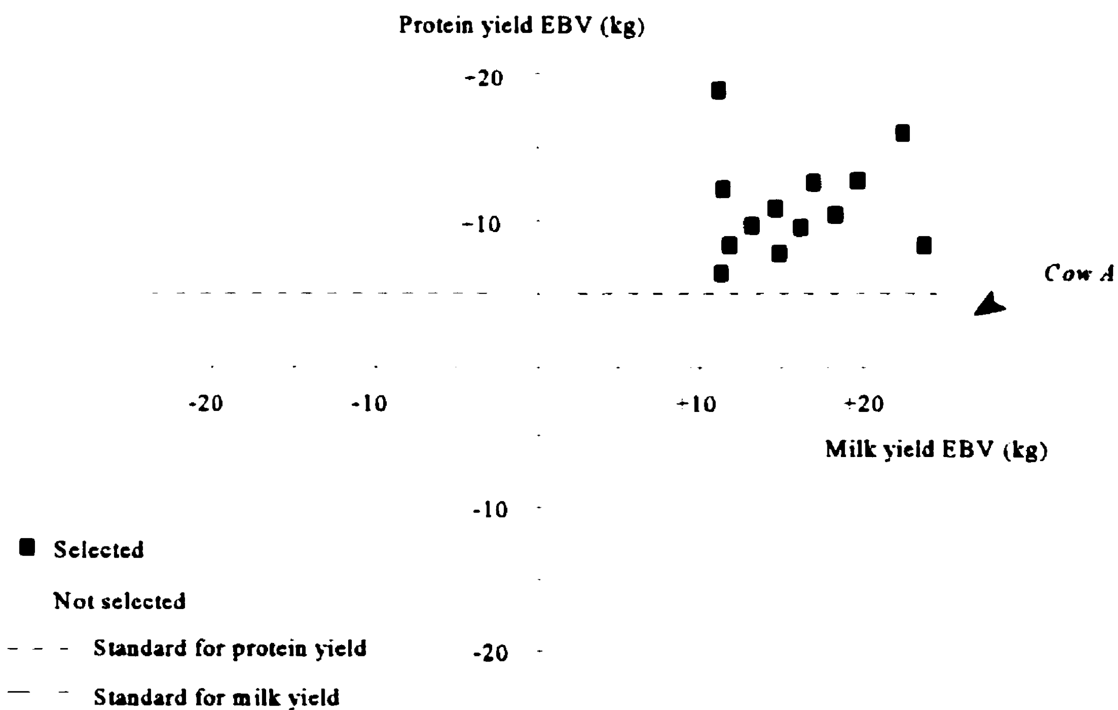


Figure 1 Illustration of independent culling levels in a set of dairy cows. Selected cows appear in the upper right portion of the plot. Their milk and protein yields EBVs exceed culling level for these traits (adapted from Bourdon, 1997)

what is not. However, this method may exclude some potentially useful animals when traits used in selection have no clear standard of merit such as milk and protein yields. For example, in figure 1, cow A, which has the highest milk yield estimated breeding value, is not selected by using this method because her estimated breeding value for protein yield is too low, though only slightly. The difficulty with this method is still to decide what the culling levels should be. Most breeders who use this method usually use an intuitive and experimental approach rather than a mathematically precise one.

Selection using a selection index is the method for which mathematical procedures are the most studied. A selection index takes into account correlations which exist between traits and allows selection of animals with particularly good estimated breeding values for one trait even if their performance in other traits is below a certain standard (Bourdon, 1997). In figure 2, the selection index is represented by the diagonal line. Cow A is now selected using this method. Her ability to produce a high amount of milk is profitable enough to counterbalance her lower genetic evaluation for protein production. The index is designed to maximise the overall genetic improvement in the population (Hazel, 1943). It combines information on several traits to produce a single number which could be called the index value, the net merit or the score of the animal. This single number expresses the overall merit of the animal and a group of individuals may be ranked according to this value. Only animals at the top are selected. Each trait in the index is associated with an economic value and this value shows the importance of the character. For example, a trait with a negative economic value means that the greater its measurement, the lower the score of this animal will be. To compute economic values, a careful analysis of costs and prices is needed. These costs and these prices vary greatly from one situation to another, and from one period of time to another.

The Canadian genetic evaluation program for dairy animals consists of estimated breeding values (EBV) on more than 40 traits. Two selection indexes which combine some of them are currently used in Canada: the Lifetime Profit Index (LPI) and the Total Economic Value index (TEV). The emphasis on each trait has been computed for each index by using a combination of actual and theoretical calculations and assumptions. The economic data used

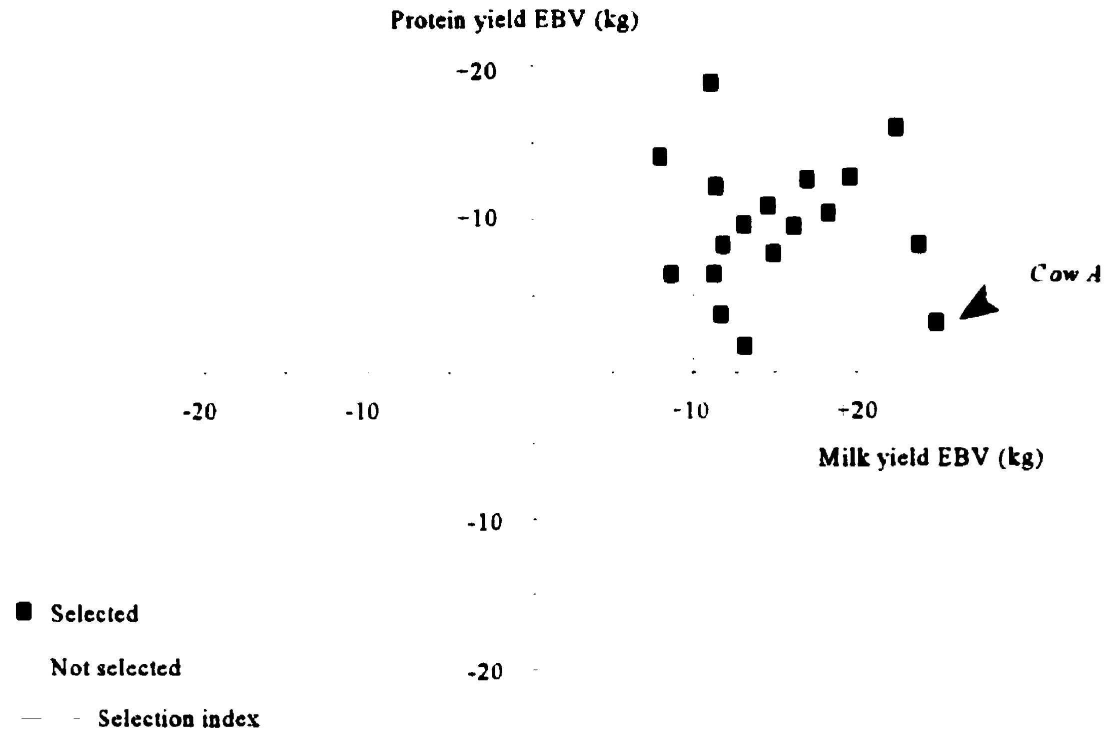


Figure 2 Illustration of index selection in a set of dairy cows. The selection index is represented by the doted diagonal line and culling levels from figure 1 are shown for comparison (Adapted from Bourdon, 1997)

to build both indexes were largely based on the Holstein breed. However, the LPI and the TEV are used not only to rank Holstein sires and cows, but also animals in the other dairy breeds (such as Ayrshires, Jerseys, Brown Swiss, Guernsey and Canadienne). Are the emphases put on traits, i.e. economic values, the same for all dairy breeds? If not, separate selection indexes would be more appropriate for each breed to really maximise the genetic improvement of each breed.

The objectives of this study were:

a) to estimate, by using field data, separate economic values of traits for each breed;

b) to determine whether different values are needed for different breeds.

Results of this study should:

a) provide an empirical check of values theoretically derived to produce LPI and TEV;

b) allow the dairy industry to see whether different LPIs and TEVs are appropriate for the different breeds.

II. Review of Literature

2.1 Selection index theory

In animal breeding, Dr. L.N. Hazel was one of the first people who tried to find a way of selecting simultaneously for several traits. This task was not easy, because it involved many principles and concepts that were being taught in statistics, genetic and animal breeding courses. Courses in statistics showed how independent variables could be chosen so as to result in a maximum correlation with a dependent variable; genetic courses showed how pleiotropic and linked gene effects might cause simultaneous effects upon two traits; and courses in animal breeding examined the relationships which exits between genotype and phenotype (Hazel *et al.* 1994). Most of the necessary ingredients had been already developed, but Hazel had to organize them to complete the puzzle.

His work on multiple-trait selection is in two papers. Hazel and Lush (1942) demonstrated in the first one that the method of total score (now called the index selection) was the most efficient way to achieve multi-trait selection, i.e. the expected genetic gain is the highest by using this method when traits and traits' parameters remain fixed. The method of independent culling levels was intermediate in efficiency while the tandem method was the least efficient of the three methods already described. Hazel (1943) subsequently published the principles of constructing and using selection indexes which, he claimed, allow for maximum genetic progress.

Hazel (1943) defined the aggregate genotype of an animal as the sum of its several genotypes (assuming a distinct genotype for each economic trait), each genotype being weighted according to a relative economic value for that trait. Animals vary in breeding value, as in phenotype, for each single trait. Aggregate genotypes for animals are a way to amalgamate information on different traits into a single equation:

$$H = a_1G_1 + a_2G_2 + ... + a_nG_n = \sum_{i=1}^{i=n} a_i G_i \qquad [1]$$

where **H** is the aggregate genotype, $\mathbf{a}_i$ is the economic value for trait$_i$, $\mathbf{G}_i$ is the additive genotypic value of trait$_i$ and n is the number of traits used to define the aggregate value of animals.

Determining the true genetic value of an individual is difficult. Some scientists are working on genome maps of different species. These maps and genetic markers may, in the future, be used to define more exactly what the genotype of an individual is. However, to date, phenotypic measurements, taken on individual and on its relatives is the usual way to evaluate its value in terms of selection. The value of an individual, judged on the mean of its progeny, is called its Breeding Value (BV). Thus, the equation [1] can be rewritten as:

$$H = a_1BV_1 + a_2BV_2 + ... + a_nBV_n \qquad [2]$$

The sum of **n** traits weighted by their economic value defines the value of an animal. **H** is the optimum selection index, i.e. if animals were ranked by using this last equation, the response to selection would be maximum. However, no method exists to compute exact breeding values of traits. They are estimated by recording information on the animal and its relatives, and some statistical errors are related to these observations. These estimates are simply called estimated breeding values (EBV). Also, some of the **n** traits included in equation [2] may be too hard or too expensive to measure, even if they are required to estimate the value of the animal. For example, in dairy cattle, somatic cell count in milk and some conformation traits are used to select for healthy udders. The longevity of animals is also an interesting trait, but impossible to measure if selection is to be made before the end of the life of the animal. Conformation traits which are correlated with the longevity of the animal are used in the selection index instead of the number of lactations that the cow survived. Another equation must be defined to account for the fact that true breeding values of animals are unknown and not all traits can be evaluated on animals. If there are *m* traits for which an estimated breeding value is computed. the selection index is defined as:

$$I = b_1EBV_1 + b_2EBV_2 + ... + b_mEBV_m \quad [3]$$

where $\mathbf{b}_i$ is the selection index coefficient for $traits_i$. The **m** traits could be the same as the traits in the aggregate breeding value. some could be the same and some could be different or all traits could be different. If a complete multi-trait BLUP evaluation is used for the computation of the EBV's on the **m** traits. then the b's [equation 3] are equal to their corresponding a's [equation 2].

The two equations. **H** and **I**. are also called respectively the selection objective and the selection criterion (Cameron. 1997). The selection is based on the selection criterion (**I**). but this index must be built to maximise the response in the selection objective (**H**). It is therefore important to use the set of selection index coefficients (**b**) which maximise this response. In order to compute them. genetic and phenotypic variances of each trait. covariances among these traits and economic values are needed. Determination of economic values. often one of the major steps in constructing a selection index. must. therefore. yield reliable and accurate estimates.

2.2 Profit as the selection objective

In practice. one of the most widespread aims of selection is to improve economic returns or profit at either the animal farm or sector level. The selection objective becomes thus equal to the profit. However. to find the appropriate definition of profit for a particular situation is not always obvious. Returns. as well as costs. must be included in this definition. For example. in dairy cattle. the amount of milk produced multiplied by the value of milk and the costs of feed inputs are. respectively. the most important return and costs. Using only the value of the milk produced is not enough since this ignores the cost of feed inputs needed to produce this milk. An increase in milk production can occur by increasing the amount of feed given to the cow, therefore an appropriate definition of profit should include these considerations.

Many authors have defined at the animal level a profit equation and used it (e.g. Jagannatha *et al.*, 1998; de Haan *et al.*, 1992; Van Arendonk, 1991; Weigel *et al.*, 1995a; Weigel *et al.*, 1995b). Depending on the structure of the dairy industry, where they worked, and data what were available, different returns and costs were included in these definitions, and the values used varied. Each of these studies attempted to be as complete as possible. Their profit equations were all built, of course, to represent as much as possible the reality they wanted to picture.

Weller (1994) described different sources of returns and costs. His descriptions apply to almost all livestock, not only dairy cows. First, he separated returns in two parts: returns from female production and returns from offspring production. Returns from female production per enterprise is defined by Weller (1994) as the number of females multiplied by the volume produced per female and the value of product per unit of volume. The main dairy cows' product sold and consumed is the milk. Through genetic engineering, other products such as pharmaceutical products may become another important source of revenue for cows in the future. Currently, these techniques are not widely used at the farm level. Therefore, these other types of products will be ignored for the purposes of this study. The quality of the product must also be considered. Payment received for the product could vary, depending on the quality. In milk production, different values for protein, fat and lactose yield instead of one single value per volume of milk is used. In Canada, penalties apply also when a producer ships milk with antibiotics or too high concentrations of somatic cells. These constituents reflect health problems in the herd and could also alter some transformation properties of milk.

Weller (1994) defined returns from offspring as the number of offspring marketed per female multiplied by the weight of offspring product and the value per unit of offspring product. The female reproductive rate greatly affects this type of revenue. For a dairy cow, despite the value of calves being low compared to the value of milk produced after calving, reproductive rate remains important to ensure that successive lactations are not too far apart.

Costs were separated by Weller (1994) also into two parts: feed costs and non-feed costs. Breeding females need food for two reasons: maintenance and production. When the product sold is offspring, feed for production consists of the feed needed to produce offspring. In dairy cattle, cows need feed for maintenance and to produce offspring, but feed to produce milk is also an important part in their feeding. Feed efficiency in the dairy industry is described by the cost of feed per kilogram of milk. The more efficient a cow is, the lower the cost per kilogram of milk is. However, to take into account maintenance feed costs as well as production feed costs, the body weight of the cow and her production must be used to determine her feed requirement. This can then be multiplied by the prices of different foods used to obtain feed costs. Although the major production cost is feed-related, there are also significant non-feed costs that should not be ignored. Labour, interest, buildings, veterinary costs and replacement of breeding females are, according to Weller (1994), major non-feed costs. Disease-related costs, even if they are significant, are absent from several studies and incomplete recording constrains researchers to frequently ignore them. Finally, the cost for breeding female replacements is an important cost. A dairy cow must be raised, housed and fed for about 2 years prior to her first lactation. This period results in many costs that producers hope they can recover by choosing the best heifers.

Each year, the Groupe de recherche en économie et politique agricole (GREPA) computes and publishes production costs for milk production, based on a representative sample of dairy farms in the province of Quebec (GREPA, 1998). Table 1 shows results for 1985 to 1998. Costs included are only those they call real costs, meaning those for which a producer has to spend money. Other costs, such as work not paid and return on investment, are involved when the production cost for milk is calculated to determine the price producers receive for the production of their cows. However, they do not appear in the table 1 because GREPA believes producers do not spend money directly on them. Profit must be large enough to pay the unpaid work, usually done by owners of the farm, as well as returns on their investments. Table 1 confirms how important feed costs are: costs for foods, bought and produced on the farm, represented 51% of total costs in 1985 to 45% in 1998. These foods are not bought or produced only for cows in milk, they are also used to feed all replacement animals raised on the farm.

Table 1 : Total real costs for milk production in Quebec (GREPA, 1998)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
DIRECT COSTS:														
Foods bought	**6.73**	**6.80**	**6.45**	**7.48**	**6.83**	**6.17**	**6.09**	**5.60**	**5.62**	**6.93**	**6.88**	**7.33**	**7.71**	**6.25**
Foods produced on the farm	8.05	8.67	7.99	8.24	8.22	8.58	7.89	7.94	8.51	8.15	8.79	9.26	8.83	9.31
Animals bought	**0.79**	**0.83**	**0.96**	**1.52**	**1.39**	**1.25**	**1.33**	**1.12**	**1.32**	**1.42**	**1.07**	**0.96**	**0.80**	**0.62**
Animals (rearing)	6.78	7.76	7.75	7.10	7.09	8.48	7.96	8.80	6.93	7.25	7.00	6.76	7.25	6.86
Veterinary costs, insemination, registration and expenses of shows	**1.42**	**1.40**	**1.49**	**1.62**	**1.76**	**1.94**	**1.88**	**1.97**	**2.21**	**2.49**	**2.21**	**2.18**	**2.41**	**2.41**
Milking supplies, barn's small equipment, litter (bought and produced) and insecticides	0.87	0.89	1.00	1.03	1.15	1.11	1.16	1.19	1.18	1.31	1.32	1.42	1.50	1.37
Contract works	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Market expenses	2.34	2.42	2.52	2.60	2.60	2.64	2.70	2.80	2.81	2.74	2.71	2.83	2.91	2.87
Renting machinery and buildings							**0.00**	**0.00**	**0.02**	**0.02**	**0.00**	**0.00**	**0.00**	**0.01**
Minus														
Stock variations	-0.38	0.19	-0.22	0.45	0.12	0.34	-0.23	-0.01	0.77	0.89	0.62	0.47	-0.02	0.28
Animals sold and calves produced	**5.96**	**5.85**	**6.46**	**6.02**	**6.05**	**6.22**	**6.35**	**6.29**	**6.07**	**6.18**	**4.95**	**3.75**	**4.26**	**4.06**
Miscellaneous milking revenue	0.03	0.01	0.04	0.02	0.08	0.04	0.01	0.02	0.06	0.09	0.07	0.06	0.04	0.13
TOTAL DIRECT COSTS	*21.38*	*22.72*	*21.88*	*23.10*	*22.79*	*23.57*	*22.88*	23.12	21.70	23.15	*24.34*	*26.46*	*27.12*	*25.23*
INDIRECT COSTS:														
Gasoline	**0.28**	**0.28**	**0.30**	**0.25**	**0.28**	**0.31**	**0.25**	**0.27**	**0.28**	**0.26**	**0.21**	**0.24**	**0.24**	**0.19**
Maintenance truck, car and licence	0.23	0.26	0.25	0.20	0.22	0.24	0.58	0.59	0.31	0.30	0.31	0.35	0.37	0.31
Maintenance equipments and hardware	**0.38**	**0.34**	**0.39**	**0.35**	**0.41**	**0.46**	**0.18**	**0.16**	**0.52**	**0.45**	**0.40**	**0.41**	**0.39**	**0.41**
Maintenance buildings	0.34	0.39	0.43	0.36	0.46	0.44	0.52	0.49	0.40	0.46	0.46	0.48	0.41	0.48
Maintenance farmyard and fence	**0.13**	**0.13**	**0.13**	**0.16**	**0.14**	**0.13**	**0.10**	**0.10**	**0.14**	**0.16**	**0.12**	**0.09**	**0.09**	**0.10**
Equipments' rental	0.01	0.02	0.03	0.01	0.03	0.02	0.07	0.05	0.06	0.12	0.18	0.13	0.11	0.09
Taxes	**0.07**	**0.06**	**0.07**	**0.06**	**0.08**	**0.05**	**0.05**	**0.05**	**0.10**	**0.12**	**0.10**	**0.14**	**0.15**	**0.19**
Insurance farm	0.41	0.44	0.45	0.45	0.45	0.45	0.47	0.52	0.48	0.48	0.49	0.52	0.52	0.56
Life insurance loan and liability	**0.19**	**0.18**	**0.19**	**0.20**	**0.23**	**0.24**	**0.21**	**0.24**	**0.28**	**0.21**	**0.26**	**0.26**	**0.25**	**0.26**
Telephone and electricity	0.64	0.70	0.73	0.78	0.77	0.81	0.83	0.89	0.86	0.87	0.79	0.77	0.75	0.72
Interest (short, middle and long term)	**1.76**	**1.79**	**1.76**	**1.58**	**1.66**	**1.64**	**1.50**	**1.20**	**1.10**	**1.14**	**1.46**	**1.31**	**1.16**	**1.35**
Salary paid	1.22	1.26	1.23	0.87	0.94	0.86	0.85	1.02	1.08	1.15	1.01	1.02	0.95	1.18
Miscellaneous	**0.29**	**0.34**	**0.43**	**0.36**	**0.49**	**0.49**	**0.30**	**0.54**	**0.65**	**0.69**	**0.64**	**0.67**	**0.69**	**0.67**
Amortization machinery	1.07	1.21	1.30	1.38	1.47	1.51	1.46	1.54	1.42	1.30	1.32	1.36	1.42	1.49
Amortization buildings and drainage	**0.59**	**0.60**	**0.71**	**0.73**	**0.76**	**0.79**	**0.83**	**0.78**	**0.81**	**0.70**	**0.78**	**0.80**	**0.84**	**0.97**
TOTAL INDIRECT COSTS	*7.61*	*8.00*	*8.39*	*7.74*	*8.39*	*8.44*	*8.20*	8.44	8.49	8.41	*8.53*	*8.55*	*8.34*	*8.96*
TOTAL REAL COSTS	**28.99**	**30.72**	**30.28**	**30.84**	**31.18**	**32.01**	**31.08**	**31.56**	**30.19**	**31.56**	**32.87**	**35.01**	**35.46**	**34.20**

2.3 Opportunity (OC) costs of postponed replacement

Van Arendonk (1991) proposed that lifetime profit should be corrected for the opportunity cost (OC) of postponed replacement, which is the average net revenue per day of an average replacement heifer. The opportunity costs of postponed replacement reflects the profit sacrificed on an average replacement cow by keeping an "old" cow. The optimum time to cull this "old" cow should be determined by comparing her expected marginal net revenues with the opportunity cost of postponed replacement. When OC are ignored, the number of cows in the herd is considered to vary with the length of herd life because we assume that no replacement would enter in the herd after culling a cow. The value of herd life computed as the economic value for this trait is thus over-emphasized. However, this is not always theoretically true. Groen *et al.* (1997) concluded that economic values will be equal for all perspectives, if the different alternative uses of production factors saved by genetic improvement assumed by these perspectives give the same returns. The way to ensure that all perspectives give the same returns is by applying the principles of the zero-profit theory described by Brascamp *et al.* (1985).

Van Arendonk (1991) derived, theoretically, the relative value of production and herd life using simulated data and different profit equations. He used a linear regression model which included herd life and first lactation production to explain variations in 3 different definitions of profit: profitability of an individual cow from first calving until her culling (lifetime profit), cow's profit expressed per day of herd life, and finally, lifetime profit adjusted for OC of postponed replacement. The regression coefficient computed for herd life using lifetime profit not adjusted was 3.6 times larger than the regression coefficient computed when an adjustment for postponed replacement was made (3.89 vs 1.09). The regression coefficient for first lactation milk production remains the same for these two definitions of profit. In another words, the effect of an increase in milk production was the same whatever adjustment for opportunity cost of postponed replacement is made, while an increase in herd life affected more the lifetime profit than the adjusted one. The relative importance of herd life to milk production was also computed by Van Arendonk (1991) as the ratio of regression coefficients. The relative importance of these traits was respectively equal to 14.5, 3.51 and 4.04 for lifetime profit, profit per day of herd life and adjusted lifetime profit. This means the value of one additional day of herd life was equal to a increase of 14.5, 3.51 or 4.09 kg of milk during the first lactation depending on the profit equation used.

Unlike Van Arendonk (1991), who used simulated data which contained only one herd and one single value for OC of postponed replacement for all cows, De Haan *et al.* (1992) used field data which came from several herds and they computed distinct adjustments for each herd and each year. Separate values reflected more realistically the expected profit of a cow calving for the first time in a particular herd-year. To compute the adjustment, regressed means of lifetime profit and length of herd life are used because many classes of herd-year contained only a few cows. Unregressed means for small classes could be misleading. De Haan *et al.* (1992) concluded adjustment of lifetime profit reduced the influence of type traits, but only slightly, because the influence of type traits is not, at the outset, important in prediction of both adjusted and non-adjusted profit.

De Haan *et al.* (1992) did not modify the OC per day over the lifetime of the cow. The profit of each lactation was reduced by the same amount determined by year of first calving of the cow. This means they assumed there is no annual phenotypic trend and the productivity of heifers does not change from one year to the next. Since the average length of productive life is low (834 days or 2.28 years) in their study, De Haan *et al.* (1992) presumed 2.28 years of trend in OC would not invalidate their conclusions.

Weigel *et al.* (1995b) investigated the effect of applying specific OC to each lactation. First they estimated the annual phenotypic trend. They found relative net income had a positive annual phenotypic trend and it was equal to about 31$ per year. Applying OC of postponed replacement specific to each herd-year of calving instead of the same as the first herd-year calving overvalued the adjusted lifetime profit. They thus concluded the first procedure more accurately expresses the value of a cow within a herd because the genetic merit of her potential replacement improves across her lifetime. This is, of course, significantly more important as the length of productive life of cows increases.

2.4 Economic values

Hazel (1943), who combined principles of economics with animal breeding, was one of the first who used the term economic value. He defined the net genetic improvement (**ΔH**) as the sum of the genetic gains (**ΔG_i**) made for several traits, weighted by the relative economic value (**a_i**) of that trait:

$$\Delta H = a_1 \times \Delta G_1 + a_2 \times \Delta G_2 + ... + a_n \times \Delta G_n \quad [4]$$

The economic value for each trait is defined by the amount by which profit is expected to increase for each unit of improvement in that trait while keeping all other traits constant (Hazel, 1943). Genetic improvements in one generation are cumulative and are also passed on to future generations. Therefore, useful economic values must be based on conditions likely to exist sometime in the future, because several generations are required for appreciable genetic change (Hazel *et al.*, 1994). Several papers have derived economic values in many different situations (e.g. Gibson *et al.*, 1992; Harris and Freeman, 1993; Dekkers, 1995; Jagannatha *et al.*, 1998). Two different approaches were generally used: the normative and the positive approaches (Groen *et al.*, 1997).

2.4.1 The normative approach

The normative approach use algebraic equations to simulate the system. One single equation, called the profit equation (described above as the breeding objective in equation 2), can be used. This equation contains economically important traits combined to portray the economic performance of animal. Economic values are derived from this equation by calculating the partial derivatives of profit with respect to each trait in the breeding objective (Bourdon, 1998). Since the derivative of the profit equation is taken, economic values are estimated for an infinitely small change in genetic merit. The limits that this assumption creates can be avoided by computing economic values each 10 or 15 years, when a substantial change in genetic merit has been made.

Brascamp *et al.* (1985) used this method to compare theoretically how economic values vary depending on the perception taken to define the profit equation. The perception taken could be, for example, per female, per individual or per unit of product. Consistency within sets of economic values derived from each perspective must be obtained to put the same emphasis on traits independently of the base of evaluation. Brascamp *et al.* (1985) stated that relative economic values are independent of the basis of evaluation if profit is set to zero by transferring it as a cost of production to the right-hand side of the equation. The relative economic values computed in this study differ from real economic values described until now in this section by an adjustment made to compare all of them to the same trait, usually milk volume. To obtain those relative values, the relative economic weight of milk, for example, is set to one and all other relative economic values are expressed as a ratio between the real economic value of a given trait and the real economic value of milk. The ratio among the economic values is usually more useful than the actual (absolute) values because the ratios are less affected by changes in economic circumstances (Kulak, 1999).

The relationship between the performance of an animal and profit is usually more complex than can be summarized in one single equation. Another method has been developed and used to compute economic values (Dekkers, 1991; Harris and Freeman, 1993). This method models the system by using more than one equation: some to simulate biological relationships and management decisions and some others to measure the profit. A bio-economic model is created and used to simulate the production of a theoretical herd or group of herds. Creation of such a model increases the precision because biological relationships are included. The model can thus track more accurately effects that a change in the genetic component of animal performance has on overall profitability (Bourdon, 1998). Parameters used as a starting point usually reflect the actual situation or the hypothetical situation under study. For example, prices of milk components could be different from those really used if the impact of a change in milk price needs to be studied. This is useful when impacts of hypothetical circumstances, not already implemented or effective, are to be studied. A planning horizon is chosen usually somewhere between 5 and 20 years. Then, the selection process is simulated and economic values are estimated from the change in profit due to a 1-

unit change in the trait from its initial level. The simulation evaluates the effect of a marginal increase in trait genetic merit on production efficiency and net income (Dekkers, 1991). In contrast to the method used by Brascamp *et al.* (1985), infinitely small changes in genetic merit of traits are not assumed since the simulation process allows us to observe how the profit fluctuates after 10, 15 and even 20 years of selection. Over these years, traits have the chance to be significantly improved.

Management decisions and economic environment must be simulated with caution in bioeconomic models. Extra profit can be obtained by rescaling the size of the enterprise, but this kind of change must not be taken into account. Only increases which come from genetic improvement of traits should be used to derive economic values. To ensure this condition is fulfilled, Smith *et al.* (1986) suggested resources should be efficiently used before, as well as after, the genetic improvement occurs to ensure increases in profit do not come from correction of inefficiencies rather than genetic improvement. Dekkers (1991) studied the potential bias in economic values for involuntary culling, conception rate and milk production when the bioeconomic model is optimized at the base level of trait (before any iteration), but not re-optimized at the new level (after desired genetic improvement is achieved), and also when sub-optimal management policies are used both at the base and the new level of the trait. Dekkers (1991) concluded that estimates of economic values of traits evaluated in his study were rather robust to the degrees and types of sub-optimality of culling and insemination decisions considered.

2.4.2 The positive approach

The second approach used to derive economic values, called the positive approach, employs field data to estimate the contribution of individual traits to overall profitability (Dekkers, 1995).The profit, defined in different ways depending on the study, is computed for a large number of animals and derived with respect to traits to determine their relative economic importance. This approach is straightforward, but a large amount of field data on milk production, foods consumed and other events which influence the profit are needed for the population under study. You cannot extrapolate economic values for a hypothetical situation as you can do with the normative approach by changing parameters of the model. The only way to compute economic values is by compiling field data on a large number of animals over several years to reduce as much as possible the standard error of estimates. The positive approach can also be qualified as an empirical method. It analyses how, in the past, genetic improvement of traits really altered the profit, while the other approach simulates what happened. When field data are available, the positive approach is more simple to use, but the flexibility of the normative approach makes this method of estimation advantageous too. For example, the impact of a change in milk price can be simulated by the bioeconomic model, but we have to wait for many years of data collection before we are able to analyse them and conclude what the impact was if we are using the positive approach. If all parameters which affect the profit were considered in the two methods, the positive approach becomes an empirical verification of estimates obtained with the normative approach.

The profit equation as well as traits included differ greatly from one study to another. The first requirement, before using this method, is the availability of a large database which contains field data from many cows. These data could come from experimental or commercial herds. The database must be complete enough to allow the computation of reliable lifetime profit. Then, a model is created to analyse profit values computed. The aim of this model is to determine which variables or traits influenced profit measurements significantly. Independent variables are chosen among information recorded for the population under study. Depending whether phenotypic or genetic values are available, regression coefficients represent how an increase in a given trait will modify the profit. Ideally, the estimated breeding values (EBV) obtained from a genetic evaluation programme should be used as independent variables. These values are good estimations of the genetic value of animal for each trait. Performances are not confounded with herd and year effects. Therefore, the partial regression coefficient obtained by regressing profit on EBV for a given trait instead of the recorded phenotypic value for this trait represents its economic value defined as a increase in profit from a unit increase in the breeding value.

2.4.3 Results obtained: Production and conformation traits

Since dairy cows are raised to sell milk, the volume of milk produced, and its composition, is a good indicator of the profitability of cows. At least one measurement of the production is always included in most models as an independent variable. De Haan *et al.* (1992) computed the lifetime profit adjusted for OC of postponed replacement of 7479 grade cows and 64 245 registered cows. The four models they used to explain variability in lifetime profit included as independent variables the first lactation milk value and different combinations of type traits. Milk value had a small significant and positive effect in all models for both grade and registered animals ($P < 0.01$). Regression coefficients computed were equal to 1.08, on average, for grade cows and 1.15 for registered cows. De Haan *et al.* (1992) also computed the phenotypic correlation between lifetime profit adjusted for OC of postponed replacement and milk value. They found for both groups of cows that first lactation product value was highly correlated with the lifetime profit (0.55 for grade cows and 0.59 for registered cows). This means cows with higher first lactation milk value tend to have larger profit during their herd life. In addition to production traits, several linear type traits were included in models. Fewer traits were significant for grade cows compared to registered cows. De Haan *et al.* (1992) attributed this difference to the lower number of observations in the grade group. For registered cows, final score, dairy form, fore udder attachment, rear udder height and udder depth showed positive and significant regression coefficients, while body depth and rear udder width presented negative and significant regression coefficients. Phenotypic correlations computed by De Haan *et al.* (1992) between lifetime profit adjusted for OC of postponed replacement were lower for conformation traits than the production trait. They varied between -0.02 to 0.10 for grade cows and between -0.01 and 0.13 for registered cows when adjustment for product value was made. Final score obtained the largest correlation in both groups.

Weigel *et al.* (1995a) also used a lifetime profit measurement adjusted for OC of postponed replacement of 433,116 daughters of 955 sires from 52,787 herd-years of first calving. They studied the importance of yield and type traits in prediction of the lifetime profit compared to number of months in milk. Standardized economic values were computed using multiple-trait transmitting abilities of cows for mature equivalent yield of milk and fat during the first lactation. The number of months in milk was also included in some models used in this study to show the importance of this trait compared to production or type traits. Economic values resulted in a weight of 1.44:1 for yield relative to the number of months in milk. However, Weigel *et al.* (1995a) concluded that, although number of months in milk was an important component of lifetime merit, yield traits have higher heritability and are measured earlier. A larger number of progeny with completed months in milk is needed to improve reliability of this trait. Standardized economic values were also computed for type traits. To mention some of them, dairy form, rump angle, rear udder height, udder depth and final score showed positive economic values, while stature, body depth, foot angle and rear udder width showed negative economic values. Weigel *et al.* (1995a) stated that interpretation of economic values for the type traits was difficult because of the correlations among traits, particularly among the udder traits. Moreover, it is important to note comparisons among studies for these traits are difficult to do especially if these studies are conducted in different countries, since the way to evaluate and score cows varies greatly from one region to another and from one breed to another.

Gibson *et al.* (1992) investigated the potential of a selection index to give an economic genetic evaluation of sires in Canada. They computed different sets of economic weights using the normative approach. Economic value for fat yield was computed in a different way compared to economic values for water, protein and lactose yields since this trait is under a quota system in Canada. All resulting values were then scaled to 1989 values using the estimated inflation in the retail price index to provide a basis of comparison. In 1991, the current price system was based on fat yield. Then, a multiple-component pricing system was proposed to take into account the larger increase in protein demand compared with fat. Gibson *et al.* (1995) derived two different sets of economic values to evaluate how they could be modified by the newly proposed pricing system, which put similar emphasis on fat and protein yield. The pricing scheme used in 1991 allocated 0.171, 6.457, 0.171 and 0.171\$/kg to water, fat, protein and lactose respectively. Economic values derived for this situation were equal to 0.1483, 3.7376, -0.4874 and -0.3101\$/kg of change in water, fat, protein and lactose yields. The proposed multiple-component pricing scheme would allocate -0.02, 5.31, 6.02 and 0.39$/kg of water, fat, protein and lactose. Economic values derived for this scheme were equal to -0.1031, 2.8257, 6.6908 and 0.0028$/kg of change in water, fat, protein and lactose yields. Gibson *et al.* (1995) also examined how different modifications in costs affected economic values, but no major alteration was found. They concluded economic values and resulting selection indexes were relatively insensitive to all the factors considered except pricing. A modification as proposed in terms of pricing system required a new derivation of the selection index used. The optimum index should be designed to match the pricing system under which the largest number of cows are lactating (Gibson *et al.*, 1995).

The discounted lifetime profit adjusted for opportunity costs were computed for 1,112 Holstein cows by Kulak *et al.* (1997). Milk revenue in the first lactation corrected for the age of cow and expressed in kg was used to find whether this trait is significant in explaining variability in profit. As in De Haan *et al.* (1992), they found a small but significant regression coefficient for milk revenue (around 1.10 with a standard error of 0.07). However, when standard partial regression coefficients (SPRC) were derived by multiplying regression coefficients by the ratio of the standard deviation for the independent variables to the standard deviation for profit measurement, Kulak *et al.* (1997) discovered that milk revenue in the first lactation was by far the greatest indicator of profit compared to age at first calving, number of days in dry period, feed efficiency and some conformation traits. Conformation traits which obtained positive and significant standard regression coefficients were the distance from the floor to the height of the point of the attachment of all teats and distance between shoulders and hook. Teat diameter and distance between the extreme lateral protrusion of the hook and pins showed negative and significant regression coefficients. Significance of quadratic effects of traits were also studied. Two conformation traits had significant quadratic effects: the distance between shoulders and hook and the distance between the extreme lateral protrusion of the hook and pins.

2.5 Changes or errors in economic values

Since there are several methodologies for computing economic values, the effects of changes in their estimates on the efficiency of index selection were studied. Characteristics of the market change over time, prices and costs fluctuate and the demand for milk changes in both qualitative and quantitative ways over a long-term period. All these modifications cause real economic values to be modified and estimates must be adjusted periodically. Economic values are also derived using statistical and mathematical methods. In the most favourable case, when we have complete information, economic values are unbiased, but have usually fairly large sampling errors (Vandepitte and Hazel, 1977). If information is lacking or only partially available, economic values are intelligent guesses rather than accurate estimates (Vandepitte and Hazel, 1977). How large should changes be in the economic values before altering the accuracy of the selection index? Errors or changes in economic values do not negate past genetic improvement, but they could result in suboptimal future genetic improvement which could have large consequences.

Vandepitte and Hazel (1977) studied effects of errors in economic values on the accuracy of a selection index derived for genetic improvement of pigs. Errors ranging from minus 200 percent to plus 200 percent were introduced separately in each economic values of the seven traits included in the selection objective. Then, they computed the loss in relative efficiency associated with these alterations. The loss in relative efficiency was defined by them as one minus the ratio of the correlation between the real aggregate genotype and the biased index to the correlation between the real aggregate genotype and the unbiased index. From results obtained, Vandepitte and Hazel (1977) concluded the losses were asymmetrical. Negative errors (underestimation of economic values) are more critical than positive errors (overestimation of economic values). For errors between minus and plus 50 percent, losses in relative efficiency were less than 1% and depended on the importance of traits. In this study, the importance of a trait was defined according to its relative economic value, its heritability and covariances that existed between this trait and the others. Larger errors (beyond the plus and minus 50 percent interval) sometimes resulted in larger losses. The greater loss in efficiency was about 76% for an error of minus 200 percent in the economic values of feed efficiency. This means the real genetic change would be 76% smaller if the biased index - the index which contained the error in the economic value of feed efficiency - was used instead of the optimal index.

Smith (1983) also studied the effects of changes in economic values on the efficiency of the selection index. He found that efficiency is largely determined by the value of the factor ah^2, the product of the economic value and the heritability of the trait. Traits with high values will dominate the index. This result also confirmed what Vandepitte and Hazel (1977) had concluded: when one trait dominates the index, the efficiency of this index will not be sensitive to changes in economic values of lower important traits, but it will be sensitive to a change in economic values of the trait which dominates. If traits are balanced (in ah^2), only changes that upset the balance will tend to reduce efficiency. To build a selection index, phenotypic and genetic variances and covariances are needed as well as economic values. Efficiency of a selection index could, thus, also be affected by these parameters. Smith's results showed that efficiency tends to be more dependent on genetic correlations among traits than on phenotypic correlations, but both affected efficiency. Finally, Smith (1983) concluded that fine tuning on economic values, such as frequent revision to accommodate small changes in markets, will not be very productive because the changes in efficiency are likely to be small.

Since selection is a long term cumulative process, it is desirable to be able to keep a stable set of economic values and, consequently, a stable selection objective to ensure genetic improvements accumulate. However, selection indexes are not insensitive to changes in economic values or genetic and phenotypic parameters. Results presented above showed that small changes do not produce large losses in efficiency. However, their impact cannot be completely ignored and sensitivity analyses are useful to picture effects of modifications in parameters used to derive economic values.

2.6 Selection indexes from around the world

Each country has its own method to calculate its selection index used to rank its bulls (or cows). The formulation of the milk pricing system, feed management and housing systems

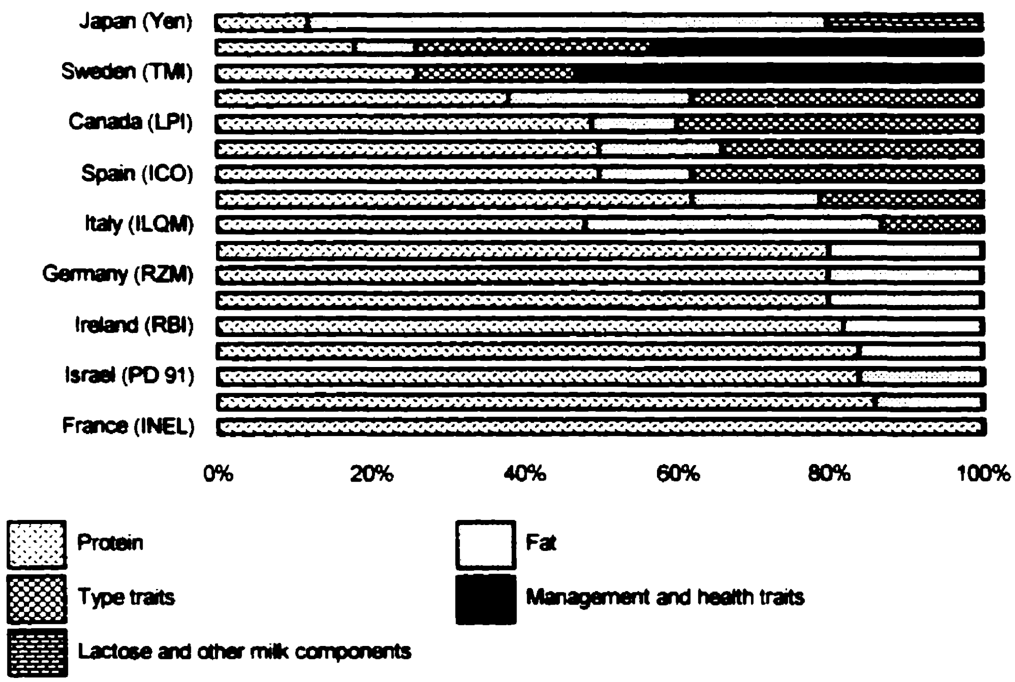


Figure 3 Selection indexes from around the world, in which the relative ratio between protein, fat, type and eventual management or health traits, have been expressed in percentages (Wesselingh, 1996)

vary greatly from one country to another. Therefore, traits included in indexes and the proportions in which they are added together differ also. Wesselingh (1996) compiled a list and compared selection criteria used in different countries. Figure 3 shows the emphasis expressed in percentages put on traits in the indexes studied by Wesselingh (1996). Although these indexes may have been modified since 1996, figure 3 still illustrates how bull rankings in different countries vary. Selection indexes are separated into two groups: the single indexes and the total indexes. Single indexes only include production traits, while total indexes also take type, health and management traits into account. Almost all single indexes strongly emphasize protein production, except for Japan for which fat production receives 68% of the index. The advantage of total indexes over single indexes is that, for the traits which are included in the index, there are no untoward effects (Wesselingh, 1996). The progress is, of course, slower per individual trait, but this progress is balanced among several economically important traits. High production results in high income, but countries which include type, management and health traits in their index know that healthy cows result in low expenditures (Wesselingh, 1996).

2.7 Selection indexes used in Canada

Canadian dairy farmers have estimated breeding values available to them for about 40 traits. Currently, two selection indices exist in Canada: the lifetime profit index (LPI) and the total economic value (TEV). Coefficients which appear in these indexes are not equal to economic values. We know from selection index theory that index coefficients (**b**) are given by:

$$b = P^{-1} G a \qquad [5]$$

where **P** is the phenotypic variance-covariance matrix of traits in the index, **G** is the genetic covariance matrix between traits in the aggregate genotype and the traits in the index and **a** is the vector of economic values. Indexes shown in this section are here principally to show which traits are included in selection in Canada.

The LPI introduced in 1990 was the first selection index to rank sires and cows for overall merit in Canada. It combines estimated breeding values (EBV) for fat and protein yields with EBVs for four conformation traits. The optimum index weights for milk, fat and protein were -1.5 : 5.1 : 6.6 and were initially computed by Gibson (Gibson *et al.* 1992 after Dekkers, 1995) because the quota system present in Canada at that time was based, first, on volume for fluid milk sales and secondly on fat sales. A partial payment for volume also existed at this time. Since an index with a negative weighting on milk was difficult to accept by producers, an index with zero weighting on milk volume was set up by the industry. This biased index was 98.5% as efficient as the optimal index and the implementation of this index was easier (Dekkers and Gibson, 1998). It is important to note that a zero weighting on milk does not mean no improvement in milk is expected. The LPI formula also includes four conformation traits because correlations between these traits and herd life were demonstrated. Genetic correlations of final score, mammary system, feet and legs and capacity with FHL were respectively 0.59, 0.57, 0.23 and 0.20 (Dekkers, 1995). Since the LPI was implemented, some adjustments have been made on the ratio of fat : protein in the LPI formula to reflect the increased market demands for protein compared with fat. The actual formula is now equal to (Canadian Dairy Network, 2000b):

$$LPI = 6\left(\frac{2EBV_{fat} - Avg.}{S.D._{fat}} + \frac{9EBV_{prot} - Avg.}{S.D._{prot.}}\right) \quad [6]$$

$$+ 4\left(\frac{5EBV_{mammary\ system}}{5.0} + \frac{4EBV_{feet\ -\ legs}}{5.0} + \frac{1EBV_{conformation}}{5.0} + \frac{1EBV_{capacity}}{5.0}\right)$$

More recently, the concept of functional herd life and somatic cell score evaluation were introduced and another selection index was developed by the Centre for Genetic Improvement of Livestock in Guelph to include these new traits: the Total Economic Value index (TEV). The formula actually used for this index is (Canadian Dairy Network, 2000a):

$$TEV = \left[\,(10 \times Production) + (4 \times Longevity) + (1.5 \times Udder\,Health)\,\right] \quad [7]$$

Where,

$$Longevity = \left(\frac{Herdlife - 3.00}{0.24}\right) \quad [8]$$

$$Production = \left(\frac{\frac{9EBV_{Protein} - Avg.}{S.D._{Prot}} + \frac{2EBV_{Fat} - Avg.}{S.D._{fat}}}{11}\right) \quad [9]$$

$$Udder\,Health = \left(\frac{\frac{-13 \times (SCS - 3.00)}{0.24} + \frac{3 \times (Milking\,speed - 69)}{5.0} + \frac{6 \times Udder\,depth}{5.2}}{17}\right) \quad [10]$$

Somatic cell score (SCS) is used to reflect the susceptibly of the cows to mastitis. As with the LPI, the TEV index weights have changed over time. They have evolved as consumer demand changed. Gibson *et al.* (1995) showed a negative index weight for fat should be included in indexes because the relative demand for fat vs protein will continue to decrease. They used a dynamic programming model to arrive at this conclusion and assumed that, over the next 20 years, demand for fat will decrease at 1% per year, protein demand will remain constant and management will improve milk, fat and protein productions per cow at a rate of 1% per year. They computed what the optimum selection index should be to rank bulls effectively and ensure that daughters produce enough milk to respond to the demand and, at the same time, maximize profit.

Response to selection obtained differs depending on which index is used: LPI improves the conformation traits more than TEV and TEV improves milk, protein and fat productions and decreases the SCS more than LPI (Lohuis and Sivanadian, 1997; Sivanadian *et al.* 1998).

Sivanadian *et al.* (1998) computed the expected sire selection responses for production and conformation traits, herd life and somatic cell score for each index separately. A sample of their results is presented in table 2. The TEV index achieved the highest

Table 2: Expected sire selection responses (expressed in BV of progeny) of 1 standard deviation of selection in a total merit index based on 50 or 100 daughter records (adapted from Sivanadian *et al.* 1998).

	n = 50		*n* = 100	
Traits:	**LPI**	**TEV**	**LPI**	**TEV**
Milk (kg)	**260.06**	**284.60**	**271.17**	**298.98**
Protein (kg)	8.77	9.27	9.18	9.71
Fat (kg)	**9.51**	**10.05**	**9.96**	**10.54**
FHL	0.055	0.045	0.062	0.052
SCS	**0.010**	**-0.009**	**0.009**	**-0.013**
Conformation	1.37	0.70	1.56	0.81
Mammary syst.	**0.98**	**0.37**	**1.14**	**0.45**
Feet & legs	1.22	0.68	1.41	0.76
Capacity	**0.69**	**0.38**	**0.75**	**0.43**

responses for milk, protein and fat traits due to the highest selection pressure on these traits in this index. LPI gave a higher response for functional herd life (FHL) even if no direct selection on this trait is made. According to Sivanadian *et al.* (1998), two reasons explain this last result. First, emphasis on type traits is higher in the LPI and conformation traits are correlated with the herd life of an animal. The second reason is that the accuracy of estimated transmitting abilities for functional herd life (ETA_{FHL}) was underestimated in this study because they only used daughter records on functional survival of the first lactation to predict ETA_{FHL}. In practise, records on survival in the second and the third lactations for daughters and other female relatives are also included and then the accuracy of estimates increases. As expected, TEV achieved the highest response for the somatic cell score. This index allowed a reduction in SCS. The susceptibility of cows to mastitis could also be decreased because this susceptibility is correlated with SCS. When the selection was based on 100 daughter records instead of 50, the response was higher because both the evaluation of bulls and their ranks were more accurate. The selection was thus more efficient.

When these two indexes were built, the economic data used were largely based on the Holstein breed. Gibson *et al.* (1992) concluded that the economic values depend on the marginal costs and returns and there is no reason to believe that they vary substantially between breeds. This means, even if the LPI and the TEV are built principally by using Holstein data, the two indexes should be appropriate for the other breeds such as Ayrshire, Jersey, Brown Swiss and Canadienne until contrary economic evidence is found (Gibson *et al.* 1992). However, for the Jersey breed, Gibson *et al.* (1992) mentioned this affirmation holds true only because it is a minor breed. A Jersey cow has a high fat to protein ratio and, if all cows in Canada were Jerseys, Canada would be substantially oversupplied with fat by using the current indexes.

As stated before, the efficiency of the selection could be affected by changes in economic values or in genetic and phenotypic parameters. Moore *et al.* (1992) used field data to compute separate genetic and phenotypic covariances and heritabilities of feed intake, production, reproduction and body weight for the Ayrshire and Holstein breeds. Then, they compared selection index coefficients obtained by using the same economic values, but the different genetic parameters previously computed. They found lower selection index weights and different relative weighting of the traits in Ayrshires when the same economic values as for Holsteins were applied to the traits. Since they found some differences between results in Holstein and Ayrshire populations, they suggested that the possible impact of differences in the genetic parameters should be investigated before concluding that the selection index proposed could be applied to other breeds. Are the economic values different for all dairy breeds as genetic parameters seem to be? As Moore *et al.* (1992) did, the only way to answer this question is by computing a set of economic values separately for each breed.

III. Materials and Methods

3.1 Data source

The economic value for a trait is defined as the increase in profit from a unit increase in the breeding value for the trait (Cameron, 1997). Therefore, if one regresses the profit produced by an animal on the genetic evaluation for each trait (in a multiple regression model), the regression coefficients will represent the economic values for each trait.

3.1.1 Test-Day records

First, to compute profit, data were obtained from the *Programme d'Analyse des Troupeaux Laitiers du Québec* (PATLQ) and consisted of 23,340,546 test-day records of dairy cows from the Province of Quebec collected between January 1980 and October 1995. Dairy cows were from 5 different breeds: Holstein, Ayrshire, Jersey, Canadienne and Brown Swiss. Since the Holstein is the most popular breed in Canada, Holstein herds comprised 90.1% of the test-day records while the balance were from the other breeds. During the period of data collection, two types of milk recording options existed: the official option, in which milking data at each test-day were collected by authorized field-supervisors, and the owner sampler option, in which the producer was responsible for performing milk recording himself. A herd could be enrolled in only one of these options at a time. It is thought that producers, enrolled in the official option (today called the supervised option), are usually more interested in selling breeding stock. Official production certificates for each lactation completed by cows in the official option are important marketing tools (Durr, 1997). Herds in the official option perform, on average, better than herds in the owner sampler option. Herds are bigger and milk production per cow is larger (PATLQ, 1996). Producers who pay for supervised milking tend to devote more attention to information obtained from PATLQ and are usually recognized as managing their herds more carefully. Historical data available contain information on all officially supervised herds plus owner sampler herds for which a reasonably accurate recording status has been determined, i.e. at least 90% sire-identified cows and 90% feedstuffs identified. This means data are available only on a selected group of owner sampler herds.

On each test-day, usually performed at monthly intervals, milk produced by cows is individually weighed. The composition of milk is also determined by laboratory analysis. The value of milk is thus available periodically for each cow during her lactation by using the pricing system employed at the moment information was collected. Cumulative milk, fat and protein produced, as well as cumulative value of milk for the current lactation, are computed at each test-day by PATLQ. Feedstuffs costs are on a herd basis at each test-day. However, the amount of feed that each cow needs is estimated according to her live weight, age, parity and production. Individual feed costs are thus available by combining this information. Feed costs include costs of maintenance and level of production. Therefore, extra costs coming from increased body weight, and extra costs associated with extra production are accounted for. It should be noted that producers have the choice of using PATLQ feed recommendations or not. Since the database does not specify whether the producer used it or not, feed costs remain estimates based on what the cow needs and according to NRC recommendations. We assume these estimates to be reasonable. The health data available are not perfect: from the PATLQ management information, data on occurrences of mastitis and other condition affecting records on the day of test are available monthly. If a cow is affected by something which could alter the milk production when this milk is weighed, this condition is recorded. Standardised estimates of costs of treating these conditions recorded allow us to obtain some costs related to the health of cows, again on an individual basis. However, if a cow is affected between two test-days and the milk recording is not affected, nothing is recorded even if this cow was treated. Breeding information is also available. Number of services required for each pregnancy is recorded. By using an estimate of costs for one service, breeding costs also become available individually for each cow. Table 3 shows the description of variables available to us at each test-day. Each line of the test-day record files represent one test-day of a cow and contains the 75 variables listed in table 3.

Table 3: Description of variables compiled at each test-day

Variable number	Description
1	PATLQ herd registration number
2	**Agricultural county**
3	Testing program
4	**Date herd registered with official program**
5	Date the herd tested
6	**Day samples were analysed**
7	Within herd 4% Fat corrected milk slope (×1000)
8	**PATLQ assigned cow number**
9	Breed of cow
10	**Breed registration or NIP number**
11	National Identification Program (NIP) letter of cow
12	**Breed of sire**
13	Breed registration number of sire
14	Breed of dam
15	**Breed registration number of cow's dam**
16	National Identification Program (NIP) letter of cow's dam
17	**Cow's registration date with PATLQ**
18	Cow's birthdate
19	**Calving date**
20	Breeding date
21	**Date cow was dried off**
22	Last test date of cow
23	**Total number of breedings**
24	Lactation number and lactation codes
25	**Code describing record status**
26	Mark designating whether lactation has been considered official or not
27	Weight of milk produced by cow on test day (kg)(×10)
28	**Amount of concentrate offered to the cow on test-day (kg) (×10)**
29	Amount of protein supplement offered to the cow on test day (kg) (×10)
30	**Test day sample fat % (×100)**
31	Test day sample protein % (×100)
32	**Last recorded weight of cow (kg)**
33	$ value of milk on test day ($/hl) (×100)
34	**Feed cost ($), base on price and quantity of ration given to cow on the day of test (×100)**
35	Cumulative milk produced for this lactation (kg)
36	**Cumulative fat produced for this lactation (kg)**
37	Cumulative protein produced for this lactation (kg) (×100)
38	**Cumulative value ($) of milk produced for this lactation (×10)**
39	Cumulative feed costs for this lactation including dry period preceding this lactation (×10)

Table 3 (continued): Description of variables compiled at each test-day

Variable number	Description
40	Cumulative feed cost for the dry period preceding this lactation (×10)
41	**Number of tests used to calculate initial rating + initial rating (# of test×1000 + initial rating)**
42	Number of tests used to calculate final rating
43	**Final rating**
44	Interval (days) between this test and last good test day
45	**Weight (kg) of milk produced on last good test day (×10)**
46	Sample fat % from last good test day (×100)
47	**Sample protein % from last good test day (×100)**
48	Flag signalling editors to check record next month
49	**Breed of last service sire**
50	Breed registration number or A.I. code of service sire
51	**Calving codes: (calf-sex×1000) + (calf-size×100) + (calf-ease×10) + (calf-survival)**
52	Feeding group, based on production of individual cow
53	**Test day sample count**
54	Lactation type
55	**Total milk produced in 305 days (kg)**
56	Total fat produced in 305 days (kg) (×100)
57	**Total protein produced in 305 days (kg) (×100)**
58	Value of milk ($) produced in 305 days (×10)
59	**Total feed costs ($) in 305 days (×10)**
60	Calcium fed (g) on test day
61	**Phosphorus fed (g) on test day**
62	Magnesium fed (g) on test day
63	**Type classification of cow/sire/dam (cow-classification ×100) + (sire-classification ×10) + (Dam-classification)**
64	Energy (MCAL) from meal offered (×100)
65	**Kg of protein from meal offered (×100)**
66	Kg of dry matter from meal offered (×100)
67	**Energy (MCAL) from base offered (×100)**
68	Kg of protein from base offered (×100)
69	**Kg of dry matter from base offered (×100)**
70	Energy (MCAL) from the protein supplement offered (×100)
71	**Kg of protein from the protein supplement offered (×100)**
72	Kg of dry matter from the protein supplement offered (×100)
73	**Indicator designating whether cow was present for entire test interval**
74	Number of days in the test interval or since entering/leaving
75	**Average body weight of the feeding group the cow is in**

3.1.2 Genetic Evaluations

Genetic evaluations for dairy cows were obtained from the Canadian Dairy Network. Files received contained both published and unpublished genetic evaluations of 2,276,438 Holstein cows, 113,198 Ayrshire cows, 68,018 Jersey cows, 13,092 Brown Swiss cows and 3323 Canadienne cows. Each line in these files corresponds to the genetic evaluation of one cow and contains the 42 variables described in table 4.

Estimated breeding values (EBV) of 9 traits are available in the cow evaluation files obtained: EBV of milk in kg, EBV of fat in kg, EBV of protein in kg, EBV of fat in %, EBV of protein in %, EBV of conformation, EBV of capacity, EBV of feet and legs and EBV of mammary system.

The four last traits are also called composite traits. They are based on the classifier inputs on 21 single descriptive traits. Traits related to the same theme are grouped into one single and more general evaluation trait. Seven composite traits, also called scorecard section, are computed, but only three of them are available in cow evaluation files (mammary system included two other composite traits: fore and rear udder). The composite trait called conformation represents the genetic evaluation of the final score computed by grouping five of the seven composite traits already described. Table 5 shows a description of scorecard sections and the approximate weight of each linear type trait in each composite trait for the Holstein breed. This table also shows which scorecard sections are included in final score and the weight of each of them.

Linear type trait descriptions, presented in table 5, are applicable to the Holstein breed. It should be noted that criteria to evaluate cows differ from one breed to another. We assume traits included in evaluation of composite traits are similar, but the score and consequently the genetic evaluations obtained for each cow are valid only within breed. Results obtained for type traits in this study are thus not comparable across breeds.

Table 4: Description of variables available in genetic evaluation files

Variable number	Description	Variable number	Description
1	Cow identification (breed, country, sex, registration number)	22	Number of sons with daughters with test-day records
2	**Cow name**	**23**	**Number of daughters with test-day records**
3	Birth date	24	Reliability for protein
4	**Sire identification**	**25**	**EBV milk kg**
5	Sire short name	26	Percentile rank milk
6	**Dam identification**	**27**	**EBV fat kg**
7	Maternal grandsire identification	28	Percentile rank fat
8	**Maternal grandsire short name**	**29**	**EBV protein kg**
9	Current processing centre	30	Percentile rank protein
10	**Current province code**	**31**	**EBV fat percent**
11	Current herd number	32	EBV protein percent
12	**Active cow flag (calving in the last two calendar years)**	**33**	**Type score**
13	Age at last calving for use in genetic evaluation	34	Type class
14	**Herds for protein**	**35**	**EBV conformation**
15	Number of lactations for protein	36	Percentile rank conformation
16	**Number of test-day records for protein**	**37**	**EBV capacity**
17	Number of supervised test day records for protein	38	EBV feet and legs
18	**Days in milk at last milk test**	**39**	**EBV mammary system**
19	Number of milk tests past first 60 days in milk in first lactation	40	LPI
20	**Number of last two test day records for milk that are supervised**	**41**	**Percentile rank LPI**
21	Average testing interval for milk in the current lactation	42	Record publication flag

Table 5: Description of composite traits (Holstein Canada, 1998)

Scorecard 1: Frame / Capacity

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
Stature	Measurement	Height at rump	extremely short	intermediate	extremely tall	9	20%
Relative height	**Linear code**	**Height at front end**	**extremely low**	**level**	**extremely high**	**7**	**8%**
Size	Measurement	Weight of animal	extremely small	intermediate	extremely large	9	20%
Chest width	**Linear code**	**Width of chest floor**	**extremely narrow**	**intermediate**	**extremely wide**	**9**	**29%**
Body depth	Linear code	Depth of body at rear rib	extremely shallow	intermediate	extremely deep	7	15%
Loin strength	**Linear code**	**Strength of vertebrae between back and rump**	**extremely weak**	**intermediate**	**extremely strong**	**9**	**8%**

Scorecard 2: Rump

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
Pin setting	Measurement	Height of pin bones relative to height of hook bones	extremely high	intermediate	extremely low	5	36%
Pin width	**Measurement**	**Point of pin to point of pin**	**extremely narrow**	**intermediate**	**extremely wide**	**9**	**42%**
Loin strength	Linear code	Strength of vertebrae between back and rump	extremely weak	intermediate	extremely strong	9	22%

Table 5 (continued): Description of composite traits (Holstein Canada, 1998)

Scorecard 3: Feet & Legs

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
Foot angle	Linear code	Angle of toe	extremely low	intermediate	extremely sleep	7	25%
Heel depth	**Linear code**	**Depth of heel on outside claw**	**extremely shallow**	**intermediate**	**extremely deep**	**9**	**15%**
Bone quality	Linear code	Flatness of bone	extremely coarse	intermediate	extremely flat	9	25%
Set of rear legs	**Linear code**	**Degree of curvature (side view)**	**extremely straight**	**intermediate**	**extremely curved**	**5**	**25%**
Rear legs - rear view	Linear code	Turn of hock when viewed from the rear	extremely hocked-in	intermediate	extremely straight	9	10%

Scorecard 4: Fore udder

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
Fore attachment	Linear code	Attachment to abdominal wall	extremely weak	intermediate	extremely strong	9	45%
Front teat placement	**Linear code**	**Teat placement from centre of quarter**	**extremely outside**	**centre**	**extremely inside**	**6**	**20%**
Front teat length	Measurement	Average length of teats	extremely short	intermediate	extremely long	5	5%
Udder depth	**Measurement**	**From hock to floor of udder**	**extremely deep**	**intermediate**	**extremely shallow**	**5**	**8%**
Udder texture	Linear code	Softness and expendability	extremely fleshy	intermediate	extremely soft	9	12%
Median suspensory	**Measurement**	**Depth of cleft (fore/rear)**	**extremely weak**	**intermediate**	**extremely strong**	**9**	**10%**

Table 5 (continued): Description of composite traits (Holstein Canada, 1998)

Scorecard 5: Rear udder

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
attachment height	Measurement	Milk secreting tissue to base of vulva	extremely low	intermediate	extremely high	9	23%
Attachment width	Measurement	Width at milk secreting tissue	extremely narrow	intermediate	extremely wide	9	23%
Rear teat placement	Linear code	Teat placement from centre of quarter	extremely outside	intermediate	extremely inside	6	14%
Udder depth	Measurement	From hock to floor of udder	extremely deep	intermediate	extremely shallow	5	12%
Udder texture	Linear code	Softness and expendability	extremely fleshy	intermediate	extremely soft	9	14%
Median suspensory	Measurement	Depth of cleft (fore/rear)	extremely weak	intermediate	extremely strong	9	14%

Scorecard 6: Mammary system

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
Fore udder	composite trait	described above	N/A	N/A	N/A	N/A	35%
Rear udder	composite trait	described above	N/A	N/A	N/A	N/A	45%
Udder depth	Measurement	From hock to floor of udder	extremely deep	intermediate	extremely shallow	5	
Udder texture	Linear code	Softness and expandability	extremely fleshy	intermediate	extremely soft	9	20%
Median suspensory	Measurement	Depth of cleft (fore/rear)	extremely weak	intermediate	extremely strong	9	

Table 5 (continued): Description of composite traits (Holstein Canada, 1998)

Scorecard 7: Dairy character

Trait	Method of evaluation	Description of evaluation	Code 1	Code 5	Code 9	Ideal code	Weight
Angularity	Linear code	Appearance of angularity	extremely non-angular	intermediate	extremely angular	9	60%
Bone quality	Linear code	Flatness of bone	extremely coarse	intermediate	extremely flat	9	10%
Udder texture	Linear code	Softness and expandability	extremely fleshy	intermediate	extremely soft	9	15%
Chest Width	Linear code	Width of chest floor	extremely narrow	intermediate	extremely wide	9	15%

Final Score

Scorecard sections	Point contribution to final score
Frame / capacity	18
Rump	10
Feet & legs	20
Mammary system	40
Dairy character	12

3.2 Data editing

Table 6 shows all editing steps performed on the original 21,038,021 Holstein test-day records in order to obtain the final 177,182 lifetime records used in subsequent analysis. Similarly, table 7 shows editing steps performed on the original 2,302,525 non-Holstein test-day records. During the creation of lifetime records, observations were separated for the four different coloured breeds. At the end of the editing procedure, lifetime records were obtained for 16,075 Ayrshire lifetime records, 1,001 Jersey lifetime records, 472 Canadienne lifetime records and 271 Brown Swiss.

The first step was to create lactation records from test-day records. Then, some of them were deleted due to abnormalities. A detailed description of how lactation and lifetime records were created will be given in sections 3.3 and 3.4. The aim of the present section is only to display and review all editing criteria used during the creation of final data sets.

Records from the Canadian Record of Performance (ROP) testing program were edited out. Only a small percentage of data were from this program which was discontinued in 1990. Only lactation records for which the calving date occurred between 01 January 1980 and 31 December 1995 were kept. Since the profit had to be computed, cows with no cumulative milk value or feed costs were removed.

Lifetime records were created by grouping lactations which belonged to the same cow. After removing cows for which the first lactation number recorded was different from 1 and cows which did not have consecutive lactation numbers, lifetime records were created for a total of 477,470 Holstein cows, 47,100 Ayrshire cows, 2,626 Jersey cows, 1,584 Brown Swiss cows and 889 Canadienne cows. By examining the identification number of cows, some cows with two different lifetime records were found. Usually, this occurred because cows in some herds were assigned to the same identification number. Cows with inappropriate disposal code were removed. An inappropriate disposal code occurs when an out of herd date was specified but no reason was recorded or when a cow disappeared from the data set during a lactation without any explanation. For these cases, it was not known whether the lactation was actually completed and whether the profit computed was realistic. Thus, those records were also removed. A high percentage of records were deleted when genetic evaluations were merged with lifetime records. Almost half of the cows for which lifetime records were built did not have genetic evaluations for production or conformation traits. Due to the minimum accuracy needed to compute them, some cows were not eligible to receive an evaluation.

Table 6: Number of records deleted at each step of editing procedure for Holstein herd

Editing Criteria	Records deleted	Records remaining
Initial number of lactation records	---	1,834,486
Cows with date of calving before date of birth	**28**	**1,834,458**
Cows with a parity number equal to 0	8,442	1,826,016
Age at first calving ≤ 18 months	**340**	**1,825,676**
Age at first calving > 44 months	6,012	1,819,664
Calving interval ≤ 300 days	**5,625**	**1,814,039**
Calving interval > 650 days	13,881	1,800,158
Records from herds outside Quebec	**0**	**1,800,158**
Records from ROP program	10,145	1,790,013
Calving occurs before Jan 1st 1980	**17,642**	**1,772,371**
Calving occurs after Jan 1st 1995	113,694	1,658,677
Cumulative milk value or feed costs equal to 0	**5,456**	**1,653,221**
Creation of lifetime records:		
Number of cows after editing lactation records	**---**	**722,543**
Cows for which the first lact. recorded is different from 1	210,195	512,348
Cows which have not consecutive lactation numbers	**3,966**	**508,382**
Records from breeds other than Holstein	30,912	477,470
Records from unregistered cows	**39,221**	**438,249**
Duplicated lifetime records	3,576	434,673
Cows with inappropriate disposal code	**73,364**	**361,309**
Cows with no EBV	171,795	189,514
Cows from herd-year-season which have only one record	**12,332**	**177,182**

Table 7: Number of records deleted at each step of editing procedure for non-Holstein herd

Editing Criteria	**Records deleted**	**Records remaining**
Initial number of lactation records	---	203,543
Cows with date of calving before date of birth	**0**	**203,543**
Cows with a parity number equal to 0	4,347	199,196
Age at first calving ≤ 18 months	**33**	**199,163**
Age at first calving > 44 months	1,079	198,084
Calving interval ≤ 300 days	**576**	**197,508**
Calving interval > 650 days	1,677	195,831
Records from herds outside Quebec	**164**	**195,667**
Records from ROP program	77	195,590
Calving occurs before Jan 1st 1980	**1,625**	**193,965**
Calving occurs after Jan 1st 1995	10,397	183,568
Cumulative milk value or feed costs equal to 0	**2,700**	**180,868**
Creation of lifetime records:		
Number of cows after editing lactation records	**---**	**78,586**
Cows for which the first lact. recorded is different from 1	24,084	54,502
Cows which have not consecutive lactation numbers	**497**	**54,005**

Table 7 (continued) : Number of records deleted at each step of editing procedure for non-Holstein herd

Editing criteria	Ayrshire		Jersey		Brown Swiss		Canadienne	
	Records deleted	Records remaining	Records deleted	Records remaining	Records deleted	Records remaining	Records deleted	Records remaining
Records from breeds other than the breed mentioned	**6,905**	**47,100**	**51,379**	**2,626**	**52,421**	**1,584**	**53,116**	**889**
Records from unregistered cows	3,028	44,072	120	2,506	668	916	98	791
Duplicated lifetime records	**3,298**	**43,802**	**6**	**2500**	**0**	**916**	**0**	**791**
Cows with inappropriate disposal code	7,756	36,046	606	1,894	199	717	178	613
Cows with no EBV	**18,364**	**17,682**	**823**	**1,071**	**367**	**350**	**100**	**512**
Cows from herd-year-season which have only one record	1,607	16,075	70	1,001	79	271	40	472

3.3 Creation of lactation records

A Fortran-77 program developed by Susan Joyal in the department of Animal Science of McGill University was used to create lactation records from test-day records. Test-day records files obtained from PATLQ constituted input files to this program (layout presented in table 3). Results obtained from the Fortran-77 program consisted of lactation records files in which each line represented one lactation. Table 8 presents a description of the 175 variables which resulted from the processus of creating lactation records from test-day records read one by one. When the first test-day record of a cow is found, the program starts to accumulate information on this lactation. The lactation record is written out when the end of the lactation is reached. To begin a lactation, the first test-day must occur before 75 days in milk.

Cumulative milk, fat and protein produced were calculated up to the last day of lactation and also up to days 60, 90, 120, 150, 180, 210, 240, 270 and 305 of the lactation if applicable. To compute all these cumulative totals, the average amount of milk (or fat and protein) produced per day between the last test-day and the test-day actually read was calculated and then added until one of the number of days mentioned above was reached. Similarly, cumulative totals of grain energy, protein and dry matter and cumulative totals of base ration energy, protein and dry matter were computed at days 60, 90, 120, 150, 180, 210, 240, 270, 305 of the lactation, at the last day of the lactation and at the end of the dry period.

Table 8: Description of variables which resulted from the processus of creation of lactation records

Variable number	Description	Variable number	Description	Variable number	Description
1	PATLQ herd registration number	19	Dry date for the current lactation	37	Total number of breedings
2	PATLQ assigned cow number	20	Calving date for the following lactation	38	Weight of cow on test 3 of lactation (kg)
3	Agricultural county	21	Dry date for the previous lactation	39	Peak 4% fat corrected test day milk (× 10)
4	Testing program	22	Breeding date no 1	40	Number of tests at peak 4% fat corrected test day milk
5	Date herd registered with official program	23	Service sire breed	41	Number of tests to 60 days in milk
6	Lactation official or non-official	24	Service sire registration	42	60 day milk kg (× 100)
7	Cow's registration date with PATLQ	25	Breeding date no 2	43	60 day fat kg (× 100)
8	Breed of cow	26	Service sire breed	44	60 day protein kg (× 100)
9	Cow registration or NIP number	27	Service sire registration	45	60 day grain energy (× 100)
10	NIP letter of cow	28	Breeding date no 3	46	60 day grain protein kg (× 100)
11	Breed of sire	29	Service sire breed	47	60 day grain dry matter kg (× 100)
12	Breed registration number of sire	30	Service sire registration	48	60 day base energy (× 100)
13	Breed of dam	31	Breeding date no 4	49	60 day base protein kg (× 100)
14	Breed registration number of cow's dam	32	Service sire breed	50	60 day base dry matter kg (× 100)
15	NIP letter of cow's dam	33	Service sire registration	51	number of tests to 90 days in milk
16	Cow's birthdate	34	Breeding date (last)	52	90 day milk kg (× 100)
17	Calving date	35	Service sire breed	53	90 day fat kg (× 100)
18	Lactation number	36	Service sire registration	54	90 day protein kg (× 100)

Table 8 (continued): description of variables which resulted from the processus of creation of lactation records

Variable number	Description
55	90 day grain energy (× 100)
56	**90 day grain protein kg (× 100)**
57	90 day grain dry matter kg (× 100)
58	**90 day base energy (× 100)**
59	90 day base protein kg (× 100)
60	**90 day base dry matter kg (× 100)**
61	Number of tests to 120 days in milk
62	**120 day milk kg (× 100)**
63	120 day fat kg (× 100)
64	**120 day protein kg (× 100)**
65	120 day grain energy (× 100)
66	**120 day grain protein kg (× 100)**
67	120 day grain dry matter (× 100)
68	**120 day base energy (× 100)**
69	120 day base protein kg (× 100)
70	**120 day base dry matter (× 100)**
71	number of tests to 150 days in milk
72	**150 day milk kg (× 100)**
73	150 day fat kg (× 100)

Variable number	Description
74	150 day protein kg (× 100)
75	**150 day grain energy (× 100)**
76	150 day grain protein kg (× 100)
77	**150 day grain dry matter (× 100)**
78	150 day base energy (× 100)
79	**150 day base protein kg (× 100)**
80	150 day base dry matter kg (× 100)
81	**Number of tests to 180 days in milk**
82	180 day milk kg (× 100)
83	**180 day fat kg (× 100)**
84	180 day protein kg (× 100)
85	**180 day grain energy (× 100)**
86	180 day grain protein kg (× 100)
87	**180 day grain dry matter (× 100)**
88	180 day base energy (× 100)
89	**180 day base protein kg (× 100)**
90	180 day base dry matter kg (× 100)
91	**number of tests to 210 days in milk**
92	210 day milk kg (× 100)

Variable number	Description
93	210 day fat kg (× 100)
94	**210 day protein kg (× 100)**
95	210 day grain energy (× 100)
96	**210 day grain protein kg (× 100)**
97	210 day grain dry matter (× 100)
98	**210 day base energy (× 100)**
99	210 day base protein kg (× 100)
100	**210 day base dry matter (× 100)**
101	number of tests to 240 days in milk
102	**240 day milk kg (× 100)**
103	240 day fat kg (× 100)
104	**240 day protein kg (× 100)**
105	240 day grain energy (× 100)
106	**240 day grain protein kg (× 100)**
107	240 day grain dry matter (× 100)
108	**240 day base energy (× 100)**
109	240 day base protein kg (× 100)
110	**240 day base dry matter (× 100)**
111	number of tests to 270 days in milk

Table 8 (continued): description of variables which resulted from the processus of creation of lactation records

Variable number	Description
112	270 day milk kg (× 100)
113	**270 day fat kg (× 100)**
114	270 day protein kg (× 100)
115	**270 day grain energy (× 100)**
116	270 day grain protein kg (× 100)
117	**270 day grain dry matter kg (× 100)**
118	270 day base energy (× 100)
119	**270 day base protein kg (× 100)**
120	270 day base dry matter kg (× 100)
121	**number of tests to 305 days in milk**
122	305 day milk kg (× 100)
123	**305 day fat kg (× 100)**
124	305 day protein kg (× 100)
125	**305 day grain energy (× 100)**

Variable number	Description
126	305 day grain protein kg (× 100)
127	**305 day grain dry matter kg (× 100)**
128	305 day base energy (× 100)
129	**305 day base protein kg (× 100)**
130	305 day base dry matter kg (× 100)
131	**305 day milk value (× 10)**
132	305 day feed cost (× 10)
133	**cumulative milk kg (× 100)**
134	cumulative fat kg (× 100)
135	**cumulative protein kg (× 100)**
136	cumulative milk value $ (× 10)
137	**cumulative feed cost (× 10)**
138	cumulative feed $ for dry period of this lactation (× 10)
139	**Total lactation grain energy (× 100)**

Variable number	Description
140	Total lactation grain protein kg (× 100)
141	**Total lactation grain dry matter kg (× 100)**
142	Total lactation base energy (× 100)
143	**Total lactation base protein kg (× 100)**
144	Total lactation base dry matter kg (× 100)
145	**dry period grain energy (× 100)**
146	dry period grain protein (× 100)
147	**dry period grain dry matter kg (× 100)**
148	dry period base energy (× 100)
149	**dry period base protein kg (× 100)**
150	dry period base dry matter kg (× 100)
151	**305 day or total protein supplement energy (× 100)**
152	305 day or total protein supplement protein kg (× 100)
153	**305 day or total protein supplement dry matter (× 100)**

Table 8 (continued): description of variables which resulted from the processus of creation of lactation records

Variable number	Description
154	(no of tests in initial rating × 100) + initial rating
155	no of tests in final rating
156	final rating
157	out of herd date
158	disposal code
159	breed of sire (calf's)
160	Registration number of sire (calf's)
161	(Calf sex × 1000) + (size × 100) + (calving ease × 10) + (calf survival)

Variable number	Description
162	(Cow classification × 100) + (Sire class. × 10) + (dam class.)
163	arithmetic mean of log somatic cell count (× 100)
164	arithmetic mean of somatic cell count (× 100)
165	number of test day records / lactation records
166	number of tests with cell count
167	dim × 100 + laccode, 1st event
168	dim × 100 + laccode, 2nd event
169	dim × 100 + laccode, 3rd event

Variable number	Description
170	dim × 100 + laccode, 4th event
171	dim × 100 + laccode, 5th event
172	dim × 100 + laccode, 6th event
173	Last good test - date
174	Last good test - milk weight × 10
175	Last good test - fat% (× 100)
176	Last good test - protein % × 100

3.4 Creation of lifetime records

Lifetime records were created by grouping into one line, called a record, information on each cow. During this process, the different measures of profitability used in this study were computed. These profitability measures were:

1. Lactation profit: Milk value minus feed, health and breeding costs for each lactation of a cow.

2. Lifetime profit: Summation of the lactation profits for all the lactations that a cow had until she was culled.

3. Profit until the end of the 5th lactation: Summation of the lactation profits up until the 5th lactation, or less if the cow was culled prior to her 5th lactation.

4. Profit per day of herdlife: Lifetime profit divided by the length of productive live (age at culling - age at first calving).

5. Lifetime profit adjusted for the opportunity cost (OC) of postponed replacement: OC of postponed replacement corresponded to the average net revenue per day of an average replacement heifer.

3.4.1 How to compare dollar values over time

To take into account that the value of one dollar has changed since 1980, all prices and returns were converted into constant 1995 dollars. The methodology used was the one described by Statistics Canada (1996a). Each month, Statistics Canada computes and publishes the Consumer Price Indexes (CPI). The CPI is defined as an indicator of the changes in consumer prices experienced by Canadians. It is obtained by comparing, over time, the cost of a fixed basket of commodities purchased by Canadian consumers in a particular year (Statistics Canada, 1996a). The All-item index expresses the average price variations for everything in the CPI basket. However, Statistics Canada publishes a number of measures of price change for different target group products. In this study, the Farm Input Price Indexes and the Farm Product Price Indexes were used. They measure respectively price changes of a basket of goods and services purchased by Canadian farmers for use in agricultural production and the change through time in the prices received for agricultural commodities at the first transaction point. These CPIs are available for Canada and also separately for each of the ten provinces.

The CPI time base, which is the period in which the index is given a value of 100, was 1986 (Statistics Canada, 1996a). This means, if the CPI All-items for Canada for 1995 was 132.1 (1986=100), consumer prices would be 32.1% higher in 1995 than in 1986.

CPI can be used to evaluate changes in the purchasing power of the Canadian dollar. Costs and returns available in the PATLQ data base are expressed in current values. Profit measures computed based on these costs and returns cannot be compared directly to one another without any adjustment because a dollar in 1980, in 1985 and in 1995 (to mention some of them) was not worth the same amount. To compare costs and returns over time, we must convert the current dollar values to constant dollar values (Statistics Canada, 1996a). 1995 was the year chosen to compare the profitability measures computed in this study. Tables 9 and 10 shows price indexes used to convert respectively price of inputs (feed and health costs) and value of milk produced by cows.

Table 9: Total farm input price index, 1986=100, Canada (Statistics Canada, 1999a)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Index	81.2	92.2	95.2	95.9	98.3	98.3	100.0	99.9	103.8	108.4

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998
Index	110.1	108.6	108.2	113.5	117.3	121.7	127.3	129.8	128.9

Table 10: Farm product price index for dairy product, 1986=100, Canada (Statistics Canada, 1996b)

Year	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**
Index	82.4	85.4	91.3	94.9	95.7	97.8	100.0	101.6

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Index	105.3	108.3	110.4	111.4	113.2	117.1	121.5	122.6

Suppose a cow, who calved in 1982, had a milk value recorded for this lactation equal to 3,850\$ and a second cow who calved in 1993 had a milk value equal to 4,590\$. These values are in current dollars. This means that dollar values are expressed at the value of milk prevailing during the period being referred to. As mentioned above, to be able to compare them, these values were converted to constant 1995 dollars. The Farm Product Price Index for 1982 is 91.3, for 1993 is 117.1 and for 1995 is 122.6 (Table 10). Milk values expressed in current 1982 or 1993 dollars are converted into constant 1995 dollars by dividing them by the corresponding price index, and then multiplying the results by the price index of the year 1995:

Cow which calved in 1982: $\frac{3{,}850\$}{91.3} \times 122.6 = 5{,}170\$$ (*constant* 1995 *dollars*)

Cow which calved in 1993: $\frac{4{,}590\$}{117.1} \times 122.6 = 4{,}805\$$ (*constant* 1995 *dollars*)

Even if, at first sight, the cow which calved in 1993 seemed to perform better, when milk values are both expressed in constant 1995 dollars, we can see that the cow that calved in 1982 performed better in terms of milk production.

3.4.2 Breeding costs

Breeding costs were computed for each cow by multiplying the number of services required to become pregnant at each parity by the cost of one service insemination. Breeding costs were estimated for each lactation, and then subtracted from lactation profit. Lactation profits were subsequently added to form lifetime profits.

Breeding costs depend on whether the producer needs a technician to accomplish insemination. In 90% of the cases, producers do not have the equipment to perform inseminations and a technician is required. In 1998, the cost per insemination were equal to 30.65$ when a technician came to the farm to perform insemination and 22.79$ when the producer had his own equipment (Yvon Loranger, CIAQ, personal communication). Both included the average cost of 18.00$ for the semen, thus the cost of only making insemination were equal respectively to 12.65$ and 4.79$. A weighted mean was computed to take into account that more producers ask for a technician to inseminate their cows. On average, the cost of a service insemination excluding the cost of the semen (18.00$) in 1998 was 11.86$ for Quebec. The cost of semen varies over time. The GREPA, which performs surveys each year on costs and returns respectively paid and received by producers in Quebec, published in 1997 a table where average costs of semen were given for each year between 1983 and 1996. Statistics Canada also publishes farm input price indexes specifically for artificial insemination products and services. By combining these sources of information, the total cost of one insemination can be found and expressed in constant 1995 dollars. Table 11 shows values used in this study.

Table 11: Cost of one insemination (labour, equipments and semen)

Calving Year	Farm input price index [1]	Semen ($) [2]	Labour and equipments ($) [3]	Total ($)
1980	58.6	2.46 [4]	4.05	6.51
1981	**63.6**	**2.67** [4]	**4.40**	**7.07**
1982	78.7	3.30 [4]	5.44	8.74
1983	**88.5**	**3.71**	**6.12**	**9.83**
1984	91.2	4.33	6.31	10.64
1985	**92.7**	**5.30**	**6.41**	**11.71**
1986	100.0	6.14	6.91	13.05
1987	**107.6**	**6.74**	**7.44**	**14.18**
1988	113.8	7.33	7.87	15.20
1989	**118.8**	**8.16**	**8.21**	**16.37**
1990	121.6	9.04	8.41	17.45
1991	**125.0**	**10.78**	**8.64**	**19.42**
1992	127.8	12.19	8.84	21.03
1993	**152.0**	**13.84**	**10.51**	**24.35**
1994	166.7	14.96	11.53	26.49
1995	**161.5**	**15.87**	**11.17**	**27.04**

[1] Statistics Canada, 1999b
[2] Yvon Loranger, CIAQ, personal communication
[3] Estimated by using prices obtained from the CIAQ for 1998 and farm input price indexes
[4] Extrapolated by using 1983 semen price and farm input price indexes for years 1980, 1981 and 1982.

3.4.3 Health Costs

In the data base obtained from PATLQ, the occurrence of some conditions which affected milking records are available. Average costs to treat four of these conditions: mastitis, milk fever, ketosis and displaced abomasum were found. Health costs were then computed for each cow individually by adding the cost of treating one of these conditions each time they occurred during the lifetime of the animals.

Ruegg and Dohoo (1997) conducted a trial in the Atlantic provinces of Canada to determine the effect of premilking teat disinfection. They reported an average cost to treat mastitis equal to 119.09 $CAN. This value included drug costs plus the value of discarded milk at market prices. Guard (1996) computed costs attributed to milk fever, ketosis and displaced abomasum for the United-States situation. His estimates included lost milk production, veterinary charges, extra work for the owner, drugs and discarded milk.

According to Guard (1996), the costs to treat milk fever, ketosis and displaced abomasum are equal to 334$US, 145$US and 340$US respectively. The value of milk used in the Guard's study is underestimated compared to Canada because milk price is lower in United States than in Canada. Costs of drug and veterinary charges are assumed similar. The exchange rate used to convert cost computed by Guard into Canadian dollar is 1.371 which was the average rate of buying one US dollar in 1996. In Canadian dollars, costs to treat milk fever, ketosis and displaced abomasum cases were equal to 457.91$, 198.80$ and 466.14$ respectively. All these costs were finally converted into current dollar of the calving year of each lactation the condition affecting milk recording occurs in, to be comparable to feed costs and milk value recorded according to the value of the money at this time.

3.4.4 Slaughter value

Each year, Agriculture and Agri-Food Canada publishes yearly average prices at public stockyards. Table 12 shows prices published and used for this study. A salvage value was computed when cows were culled or sold using the last weight recorded and the average price published by Agriculture and Agri-Food Canada for the calving year. When no weight was recorded, an average weight specific for each parity and breed was used. Average weights were found by using the MEANS Procedure of SAS/STAT®. No salvage value was computed for cows that died and, since we do not have information on how much money producers received when they sold their animals, a salvage value was computed for these cows to compensate.

Table 12: Yearly average prices on public stockyards (Montreal or Ste-Hyacinthe) (From Agriculture and Agri-Food Canada)

Year	Prices published ($ per 100 lb) [1]	Prices converted per kg
1980	58.09	1.28
1981	**53.75**	**1.18**
1982	50.45	1.11
1983	**48.56**	**1.07**
1984	50.44	1.11
1985	**50.94**	**1.12**
1986	N/A	1.20 [2]
1987	**57.74**	**1.27**
1988	55.67	1.22
1989	**55.77**	**1.23**
1990	N/A	1.22 [2]
1991	**55.06**	**1.21**
1992	N/A	1.27 [2]
1993	**60.18**	**1.33**
1994	57.42	1.27
1995	**47.56**	**1.05**

[1] Arithmetic average of prices given for cows from class D1, D2 and D3

[2] Extrapolated by computing the arithmetic mean of prices of the previous and the following year

3.5 Estimation of opportunity cost (OC) of postponed replacement

The procedure used to estimate lifetime profit adjusted for opportunity cost of postponed replacement was similar to the one described by de Haan *et al.* (1992) and Weigel *et al.* (1995). This adjustment was made to reflect the profit sacrificed on an average replacement cow by keeping an old cow one extra lactation. The OC must therefore reflect the average profit produced by a cow calving for the first time in the same herd and year as the cow in question (de Haan *et al.*, 1992). The lifetime profit adjusted for OC of postponed replacement was calculated as:

$$LTPOC_{ht} = LTP_{ht} - \sum_{j=1}^{n} \left[(DIM_{hij} + DDRY_{hij}) \times OCPD_{hj} \right] \qquad [11]$$

where $\mathbf{LTPOC_{hi}}$ is the lifetime profit adjusted for OC of postponed replacement of the cow h in the herd i. $\mathbf{LTP_{hi}}$ is the lifetime profit calculated as described earlier in this section. $\mathbf{DIM_{hij}}$ is the number of productive days during the lactation initiated during year j of the cow h in the herd i. $\mathbf{DDRY_{hij}}$ is the total days dry preceding the same lactation and $\mathbf{OCPD_{hj}}$ is the OC per day specific to all lactations initiated during year j of the herd i. A different OC was used for each lactation initiated by cows to take into account the genetic trend which occurred during the length of productive life of cows. The OCPD was calculated as:

$$OCPD_{hj} = rHYLTP_{hj} \; / \; rHYDPL_{hj} \qquad [12]$$

where $\mathbf{rHYLTP_{hj}}$ and $\mathbf{rHYDPL_{hj}}$ are respectively regressed mean for herd-year LTP and length of productive live (DPL). Regressed means were used because some herd-year classes contained very few cows which calved for the first time. Unregressed means for small classes could be misleading. The regression procedure placed increasing emphasis on overall herd average LTP and DPL for herd-year classes with few observations (de Haan *et al.*, 1992). Regressed means were calculated as follows:

$$rHYLTP_{hj} = HLTP_h + [(n_{hj}/(n_{hj} + \delta)) \times (HYLTP_{hj} - HLTP_h)] \qquad [13]$$

$$rHYDPL_{hj} = HDPL_h + [(n_{hj}/(n_{hj} + \delta)) \times (HYDPL_{hj} - HDPL_h)] \qquad [14]$$

where $\mathbf{HLTP_h}$ = mean for LTP in herd h

$\mathbf{HYLTP_{hj}}$ = mean for LTP in year j in herd h

$\mathbf{HDPL_h}$ = mean for DPL in herd h

$\mathbf{HDPL_{hj}}$ = mean for DPL in year j in herd h

$\mathbf{n_{hj}}$ = number of cows first

calving during year j within herd h

and $\delta = \dfrac{\sigma_e^2}{\sigma_y^2(h)}$ = error variance for LTP or DPL over variance of LTP or DPL for year within herd

A Fortran-90 program was written to extract lifetime profit and length of productive life for each cow in the data for which a culling code was recorded. This means lifetime profits and lengths of productive life used to compute OC came from cows, known not to have been sold or where owner did not stop taking records during one lactation. This ensured the productive life of cows were not finished prematurely. Means and number of cows within each herd-year were found by using the MEANS Procedure of SAS/STAT®. Variances for year within herd and error variances for the two variables were computed by using the MIXED Procedure of SAS/STAT®. We used δ values of 14.18 for LTP and 8.15 for DPL.

3.6 Statistical model

The five different profitability measurements were computed for each cow and genetic evaluations recorded were combined with these measurements. For each breed and each testing program (Official and Owner-sampler), measures of profit were regressed on the estimated breeding values for each trait. The model used was an analysis of covariance and was defined as:

$$\begin{aligned} \text{Profit}_{ij} = \; & \mu + \text{herd-year-season}_i + b_1 \cdot EBV_{\text{milk } ij} + b_2 \cdot EBV_{\text{fat } ij} + b_3 \cdot EBV_{\text{protein } ij} + \\ & b_4 \cdot EBV_{\text{conformation } ij} + b_5 \cdot EBV_{\text{capacity } ij} + b_6 \cdot EBV_{\text{feet \& legs } ij} + \\ & b_7 \cdot EBV_{\text{mammary system } ij} + e_{ij} \end{aligned} \qquad [15]$$

where Profit_{ij} is the profit for the j^{th} cow in the i^{th} herd-year-season, $EBV_{\text{trait } ij}$ are estimated breeding values for traits mentioned for the j^{th} cow in the i^{th} herd-year-season.

Herd-year-season effects, considered as random effects, were included in the model in an attempt to remove any management differences. The MIXED procedure of SAS/STAT® was used to fit this model. The regression coefficients (b_1 to b_7) are equal to the economic values for each trait because they are the partial regressions of profit on breeding values, i.e. the change in profit per unit change in breeding value for each trait. Computing regression coefficients separately for each breed and testing programs allowed us to see whether the regression coefficients (economic values) are similar or dissimilar across breeds and testing programs.

IV. Results and discussion

4.1 Truncation effect

The data set used contained information on lactations of cows which calved between January 1980 and December 1994. Only cows for which information was available for all their productive life (from their first calving to their culling) within this period of time were kept. When a specific period of time is selected as in this project, truncation effects usually occur. Figure 4 shows the effect of the truncation of data on profitability measurements. The evolution of lifetime profit and profit until the end of the fifth lactation are shown over time. These profitability measurements dropped after 1989 because cows which calved for the first time between 1990 and 1994 did not have the opportunity to complete as many lactations as the group of cows which calved for the first time between 1980 and 1989. For example, within the group of cows which calved for the first time in 1994, the consequence of the truncation of data was only cows which were culled after one lactation were kept in the data set. Cows which survived for more than one lactation were removed from the data set because their culling date occurred outside the period of time chosen. Thus, means of profits which appear in figure 4 for the year 1994 are only means of cows which calved for the first time in 1994 and survived for only one lactation. Cows which survived for more than one lactation and which were likely to have higher lifetime profits were removed from the data set because information about their subsequent lactations was not found within the period chosen. Figure 4 shows only results for the Holstein and Ayrshire breeds, but the pattern is also repeated for the Jersey. Brown Swiss and Canadienne breeds. Results for these three last breeds are shown in figures A1 (in appendix).

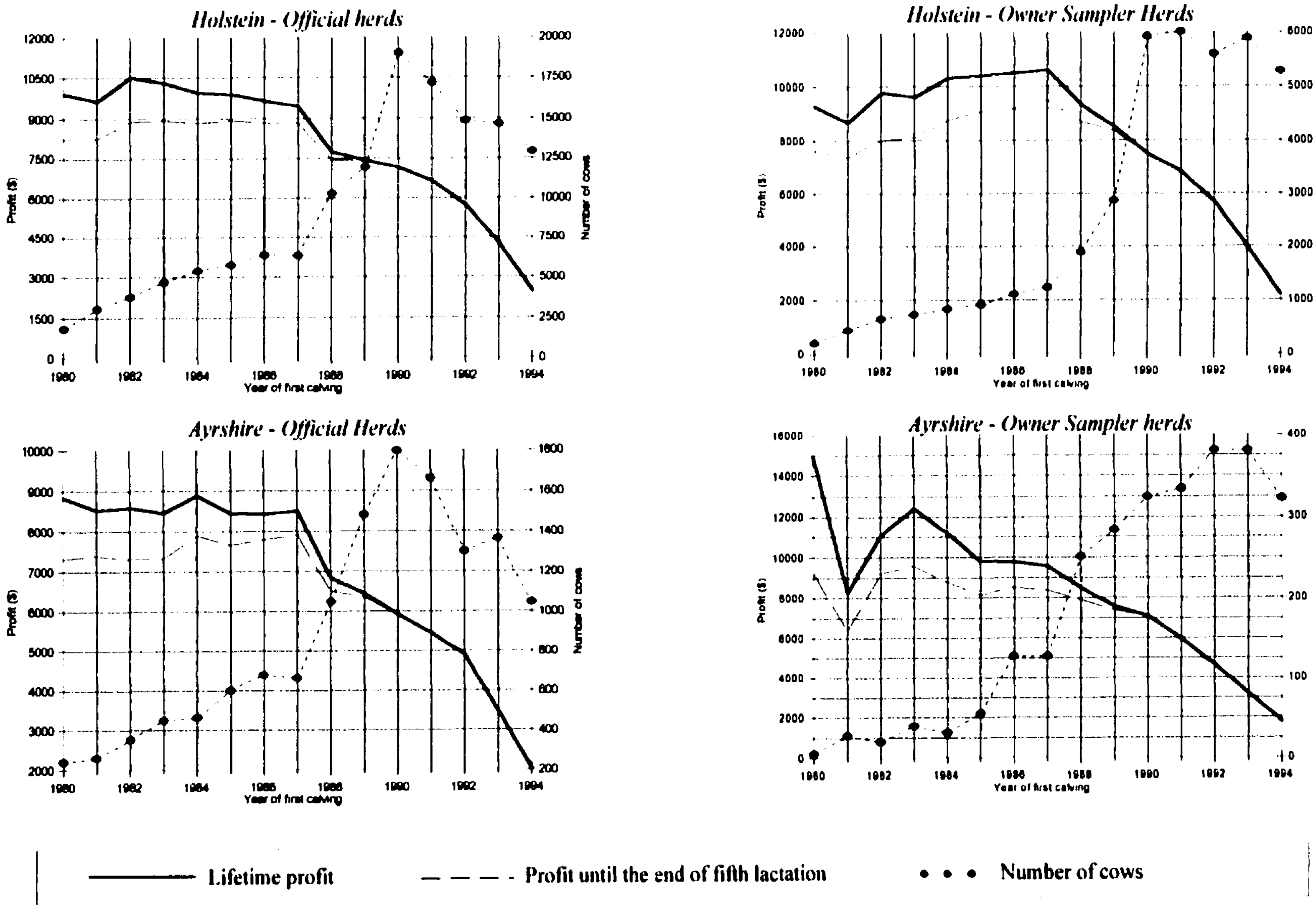


Figure 4 Progression of means of lifetime profit, means of profit until the end of fifth lactation and number of cows by year of first calving

The mean of lifetime profits for the group of cows which calved for the first time between 1990 and 1994 in the data set are thus not representative. For this reason, only lifetime profit and profit until the end of the fifth lactation of cows which calved for the first time between January 1980 and December 1989 were used in this analysis.

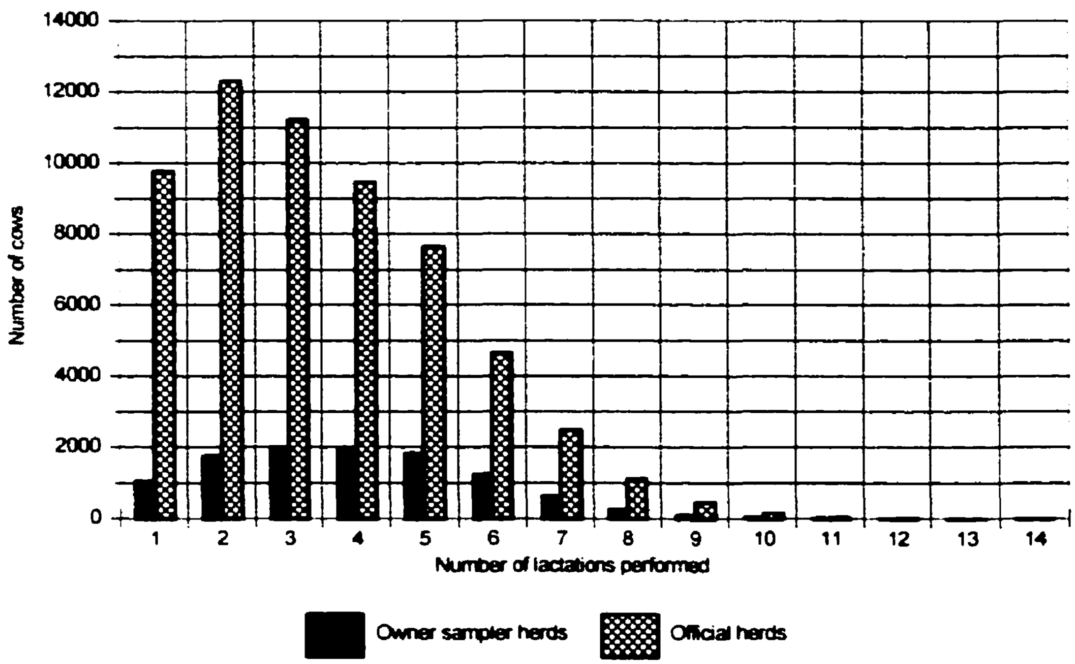
Figure 4 also shows that means of lifetime profit are similar to means of profit up to the end of fifth lactation. About 85% of cows produced for 5 lactations or less. This means only 15% of cows had a lifetime profit different from their profit until the end of the fifth lactation. Table 13 shows means of length of productive life for each breed and recording option. Productive life is defined as the interval between the first calving of the cow and her culling. Figure 5 shows distribution of length of production life for the Holstein and Ayrshire breeds and Figure A2 (in appendix) shows distributions of length of production life for the Jersey, Brown Swiss and Canadienne breeds.

Jagannatha *et al.* (1998) reported survival rates higher than what were found here. About 57% of cows born between 1980 and 1988 survived beyond the second lactation and about 27% beyond the fifth lactation. Surprisingly, the average length of productive life found by Jagannatha *et al.* (1998) was lower than means computed in this study except for the Canadienne breed. The herd life mean they calculated was equal to 832 days with a standard deviation of 585 days. Kulak *et al.* (1997) found an average of 998 days between the first calving and death or culling with a standard deviation of 647 days. All these estimates (including those in table 13) are associated with large standard deviations. Thus, there is a great variability in length of productive life among cows and comparing results which come from different studies is difficult.

Table 13: Means and standard deviations of length of productive life

Breed	Official Herds			Owner Sampler Herds		
	N	Mean (days)	Std Dev.	N	Mean (days)	Std Dev.
Holstein	**56276**	**1184.8**	**753.9**	**9794**	**1368.8**	**741.4**
Ayrshire	5837	1216.1	737.1	837	1507.6	733.6
Jersey	**180**	**1091.9**	**715.2**	**23**	**1724.8**	**824.5**
Brown Swiss	44	1128.7	680.5	14	1337.4	574.8
Canadienne	**114**	**675.6**	**563.3**	**7**	**848.7**	**535.1**

Holsteins



Ayrshires

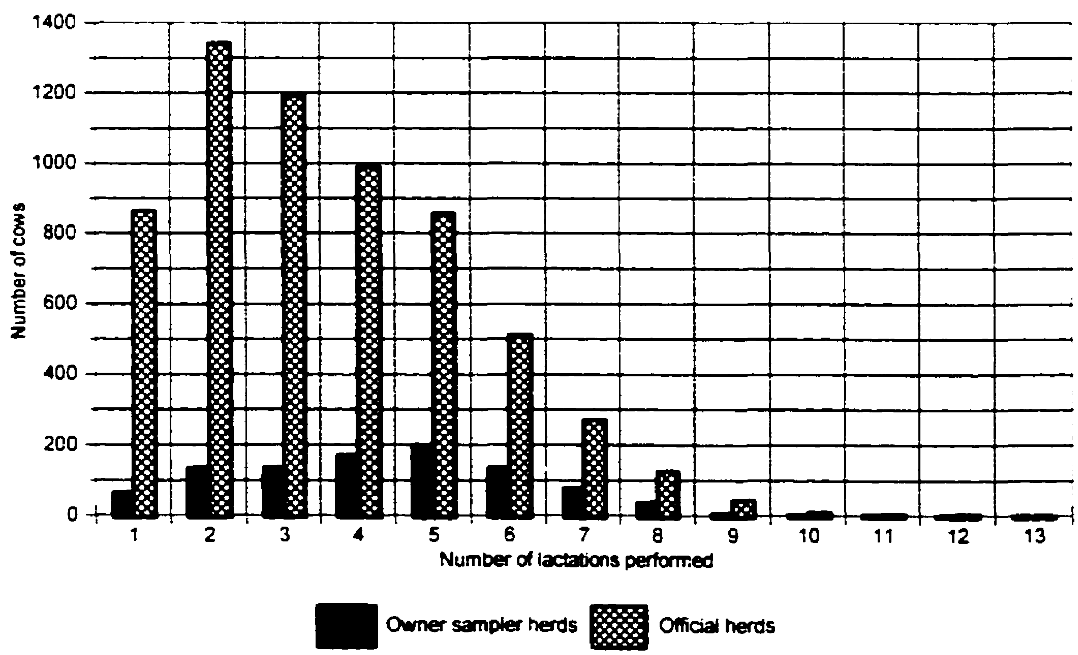


Figure 5 Distribution of cows according to the number of lactation performed

4.2 Profitability measurements

Means, standard deviations, and ranges for measures of profitability are in tables 14.1 through 14.4. The Holstein breed had the highest means for lifetime profit, profit until the end on the fifth lactation as well as profit per day of herd life. The Canadienne breed had the lowest lifetime profit and profit until the end of the fifth lactation, far behind the four other breeds. In its production report (PATLQ, 1996) published separately for each breed the annual average milk production for the province of Quebec. According to this report, the Holstein breed had the highest average milk production followed by the Ayrshire and Brown Swiss breeds which had similar milk production, and then, by the Jersey and Canadienne breeds which had also similar milk production. Milk production is not of course the only thing which explains the profit of cows, but the rank of means for lifetime profit and profit until the end of the fifth lactation are similar to the rank of means for milk production published by PATLQ except for the Jersey breed which had profits higher than expected.

Brown Swiss cows in official herds of and Jersey cows in owner sampler herds of had the highest means for lifetime profit adjusted for OC of postponed replacement. According to the definition of profit adjusted for OC of postponed replacement, this measure of profit should theoretically be equal to zero (Van Arendonk, 1990; Kulak *et al.*, 1997a). The deviation from zero and large variabilities reported are explained probably in part by errors associated with data recording and estimations made during the computation of profitability measurements.

Surprisingly, cows in owner sampler herds had, on average, higher profits than cows in official herds except in the case of profit per day of herd life. PATLQ (1997) reported official herds produced on average 15% more milk per lactation than owner sampler herds and fat and protein percentages were also higher. PATLQ (1997) also reported official herds had on average longer calving interval than owner sampler herds. Table 13 already showed that cows in owner sampler herds had, on average, longer herd life, maybe due to a lower selection pressure applied in owner sampler herd as compared to official herds or maybe due to higher longevity in owner sampler herds. Longer productive life could explain, in part, why these cows had higher lifetime profit than cows in official herds.

Table 14.1: Basic statistics for lifetime profit for the different breeds

Breed	Option	N	Mean ($)	Std Dev.	Minimum	Maximum
Holstein	Official	59,309	9,015.42	6,047.12	-3,453.50	50,963.50
	Owner Sampler	**10,791**	**9,561.56**	**5,442.23**	**612.70**	**35,135.50**
Ayrshire	Official	6,215	7,764.83	4,863.41	159.90	29,953.10
	Owner Sampler	**966**	**8,939.48**	**4,587.36**	**673.60**	**26,428.10**
Jersey	Official	203	7,207.75	5,136.21	636.60	26,314.10
	Owner Sampler	**32**	**8,122.33**	**3,598.89**	**931.40**	**14,676.60**
Brown Swiss	Official	56	8,371.98	5,435.30	1,122.80	23,184.40
	Owner Sampler	**17**	**8,747.05**	**4,333.62**	**2,524.00**	**17,014.60**
Canadienne	Official	116	3,355.17	2,648.51	459.30	12,373.10
	Owner Sampler	**7**	**4,688.14**	**3,099.90**	**1,575.30**	**8,552.10**

Table 14.2: Basic statistics for profit until the end of the fifth lactation for the different breeds

Breed	Option	N	Mean ($)	Std Dev.	Minimum	Maximum
Holstein	Official	59,309	8,248.72	4,758.70	-3,453.50	30,338.60
	Owner Sampler	**10,791**	**8,611.87**	**4,172.55**	**612.70**	**23,457.00**
Ayrshire	Official	6,215	7,138.83	3,850.64	159.90	21,373.30
	Owner Sampler	**966**	**7,977.51**	**3,500.94**	**673.60**	**20,535.90**
Jersey	Official	203	6,588.55	4,210.80	636.60	18,333.20
	Owner Sampler	**32**	**6,737.82**	**2,514.26**	**931.40**	**9,972.20**
Brown Swiss	Official	56	7,852.15	4,419.65	1,122.80	15,723.20
	Owner Sampler	**17**	**8,092.91**	**3,504.68**	**2,524.00**	**15,752.70**
Canadienne	Official	116	3,286.07	2,504.06	459.30	12,373.10
	Owner Sampler	**7**	**4,688.14**	**3,099.90**	**1,575.30**	**8,552.10**

Table 14.3: Basic statistics for profit adjusted for OC of postponed replacement for the different breeds

Breed	Option	N	Mean ($)	Std Dev.	Minimum	Maximum
Holstein	Official	56,276	514.04	1,922.20	-10,773.80	25,329.30
	Owner Sampler	**9,794**	**808.54**	**1,847.85**	**-4,477.00**	**11,551.50**
Ayrshire	Official	5,837	649.13	1,684.36	-2,733.00	11,269.60
	Owner Sampler	**837**	**973.52**	**1,760.65**	**-2,589.10**	**9,274.90**
Jersey	Official	180	1,408.50	2,172.08	-1,872.80	9,588.00
	Owner Sampler	**23**	**2,626.62**	**2,495.17**	**-1,136.00**	**8,174.70**
Brown Swiss	Official	44	1,559.47	2,144.64	-1,760.60	6,887.70
	Owner Sampler	**14**	**1,314.02**	**2,007.08**	**-731.90**	**5,557.60**
Canadienne	Official	114	378.76	1,514.40	-1,352.80	6,631.10
	Owner Sampler	**7**	**629.54**	**942.92**	**-832.50**	**1,822.30**

Table 14.4: Basic statistics for profit per day of productive life for the different breeds

Breed	Option	N	Mean ($)	Std Dev.	Minimum	Maximum
Holstein	Official	56,276	7.74	2.61	-3.40	78.60
	Owner Sampler	**9,794**	**6.84**	**1.86**	**1.80**	**57.10**
Ayrshire	Official	5,837	6.48	2.12	2.60	46.30
	Owner Sampler	**837**	**5.75**	**1.17**	**3.00**	**13.20**
Jersey	Official	180	6.00	1.66	1.30	18.20
	Owner Sampler	**23**	**4.06**	**0.43**	**3.10**	**5.00**
Brown Swiss	Official	44	6.73	1.52	2.10	11.20
	Owner Sampler	**14**	**6.12**	**0.95**	**3.80**	**7.5**
Canadienne	Official	114	5.54	1.76	2.50	12.80
	Owner Sampler	**7**	**5.40**	**1.09**	**3.20**	**6.40**

Even if cows in official herds had on average shorter productive life and consequently lower average lifetime profit, their profit per day remains greater than cows in owner sampler herds.

Means of revenues and costs were computed separately to see if lower average lifetime profits of cows in official herds resulted from lower milk revenues or higher costs than cows in owner sampler herds. Tables 15.1 to 15.5 contain means, standard deviations for milk and salvage revenues as well as for feed, breeding and health costs separately for each breed and recording option. Once again, higher average productive life (table 13) could explain why cows in owner sampler herds had higher lifetime milk revenue and feed costs than cows in official herds.

Figures 6.1 to 6.4 and 7.1 to 7.4 show distributions of lifetime profit, profit until the end of the fifth lactation, lifetime profit adjusted for opportunity cost of postponed replacement and profit per day respectively for the Holstein and Ayrshire breed. Histograms for the Jersey, Brown Swiss and Canadienne breeds are shown in figures A2 (Appendix). Profitability measurements did not seem to be normally distributed with more profits on the low side.

Table 15.1: Means and standard deviations for lifetime milk revenue

Breed	Official herds			Owner Sampler herds		
	N	Mean ($)	Std Dev.	N	Mean	Std Dev
Holstein	**59,309**	**12,488.68**	**8,659.24**	**10,791**	**13,273.20**	**7,721.22**
Ayrshire	6,215	10,996.90	7,121.57	966	12,685.04	6,614.52
Jersey	**203**	**9,787.22**	**7,096.57**	**32**	**11,198.89**	**5,075.13**
Brown Swiss	56	11,393.67	7,617.08	17	11,966.34	5,954.23
Canadienne	**116**	**4,361.21**	**3,855.65**	**7**	**6,131.10**	**4,327.98**

Table 15.2: Means and standard deviations for salvage revenue

Breed	Official herds			Owner Sampler herds		
	N	Mean ($)	Std Dev.	N	Mean	Std Dev
Holstein	**59,309**	**560.75**	**206.26**	**10,791**	**526.89**	**226.86**
Ayrshire	6,215	476.44	181.78	966	434.81	219.81
Jersey	**203**	**344.53**	**160.11**	**32**	**242.49**	**179.27**
Brown Swiss	56	468.49	253.96	17	484.77	240.24
Canadienne	**116**	**446.40**	**110.21**	**7**	**441.07**	**57.97**

Table 15.3: Means and standard deviations for lifetime feed costs

Breed	Official herds			Owner Sampler herds		
	N	Mean ($)	Std Dev.	N	Mean	Std Dev
Holstein	**59,309**	**3,843.09**	**2,601.73**	**10,791**	**4,043.97**	**2,285.43**
Ayrshire	6,215	3,514.03	2,247.35	966	3,947.25	2,011.30
Jersey	**203**	**2,757.64**	**1,933.77**	**32**	**3,137.51**	**1,385.29**
Brown Swiss	56	3,290.58	2,075.04	17	3,532.46	1,615.48
Canadienne	**116**	**1,362.24**	**1,172.03**	**7**	**1,772.13**	**1,205.07**

Table 15.4: Means and standard deviations for lifetime breeding costs

Breed	Official herds			Owner Sampler herds		
	N	Mean ($)	Std Dev.	N	Mean	Std Dev
Holstein	**59,309**	**163.85**	**121.85**	**10,791**	**181.13**	**112.10**
Ayrshire	6,215	167.50	116.23	966	206.50	118.85
Jersey	**203**	**133.98**	**92.21**	**32**	**178.05**	**66.10**
Brown Swiss	56	166.44	105.45	17	171.60	91.63
Canadienne	**116**	**80.56**	**74.73**	**7**	**111.90**	**83.18**

Table 15.5: Means and standard deviations for lifetime health costs

Breed	Official herds			Owner Sampler herds		
	N	Mean ($)	Std Dev.	N	Mean	Std Dev
Holstein	**59,309**	**27.06**	**87.71**	**10,791**	**13.43**	**62.80**
Ayrshire	6,215	26.98	85.62	966	26.63	86.92
Jersey	**203**	**32.38**	**104.33**	**32**	**3.49**	**19.75**
Brown Swiss	56	33.15	80.15	17	0.00	0.00
Canadienne	**116**	**9.63**	**31.48**	**7**	**0.00**	**0.00**

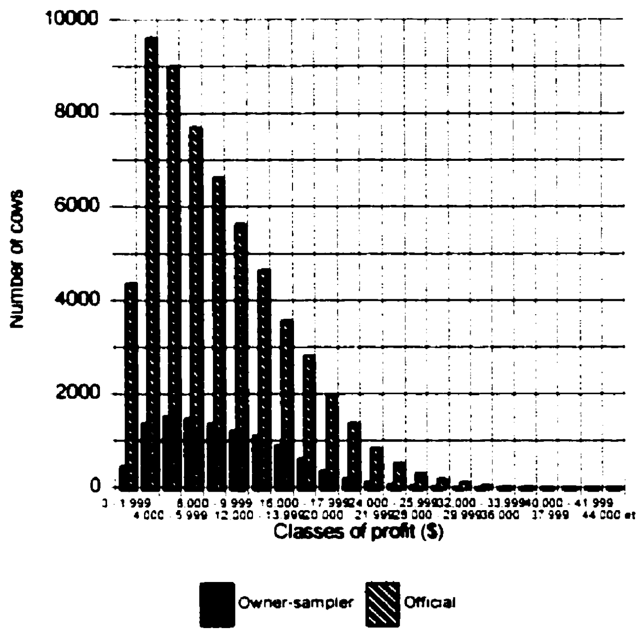


Figure 6.1 Distribution of lifetime profit for Holstein

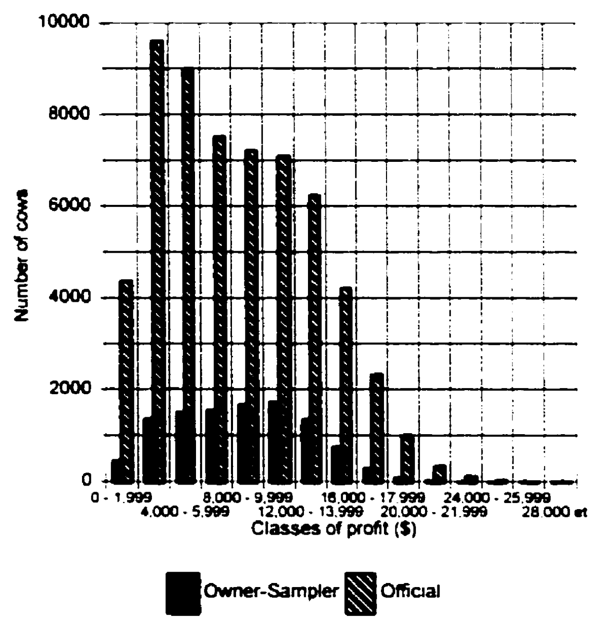


Figure 6.2 Distribution of profit until the end of fifth lactation for Holstein

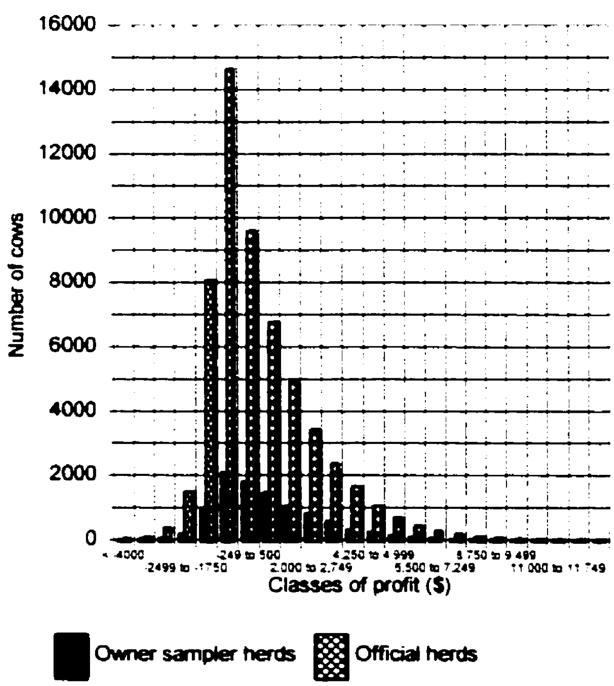


Figure 6.3 Distribution of lifetime profit adjusted for OC for Holstein

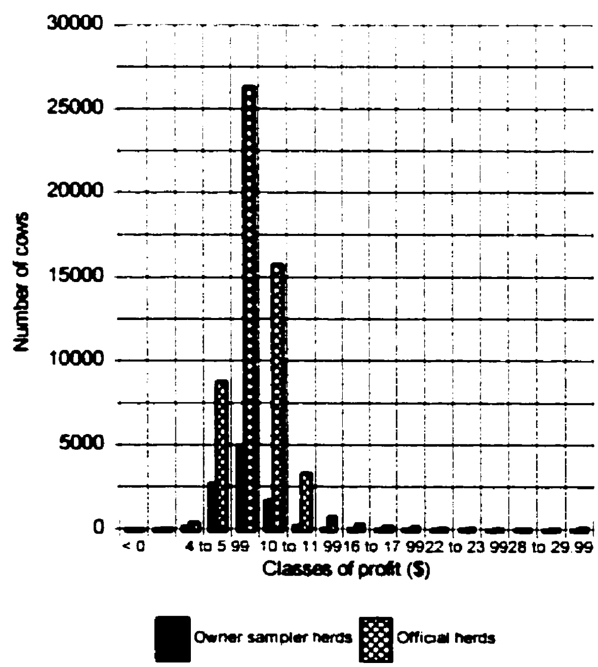


Figure 6.4 Distribution of profit per day for Holstein

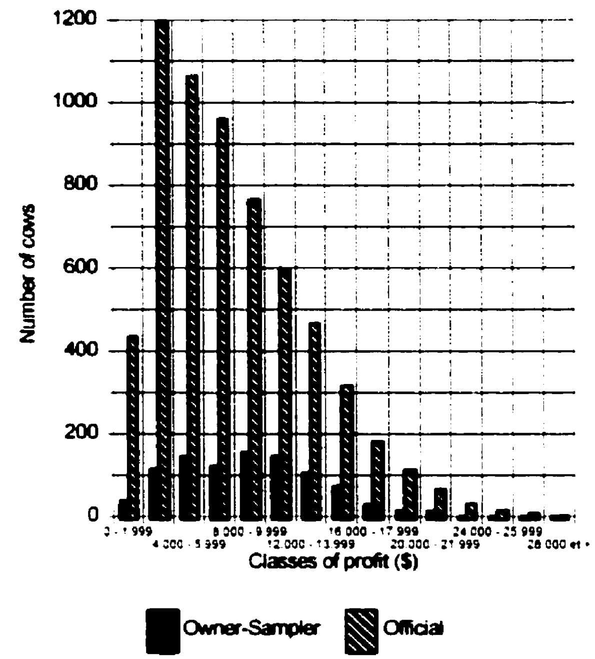


Figure 7.1 Distribution of lifetime profit for Ayrshires

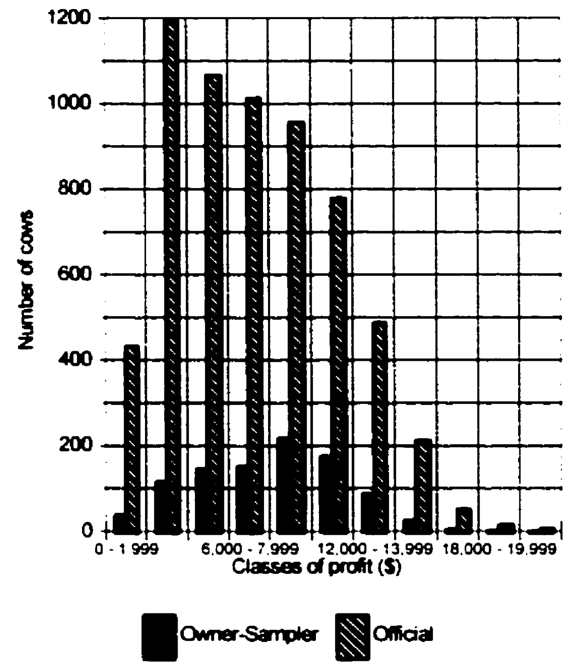


Figure 7.2 Distribution of profit until the end of fifth lactation for Ayrshires

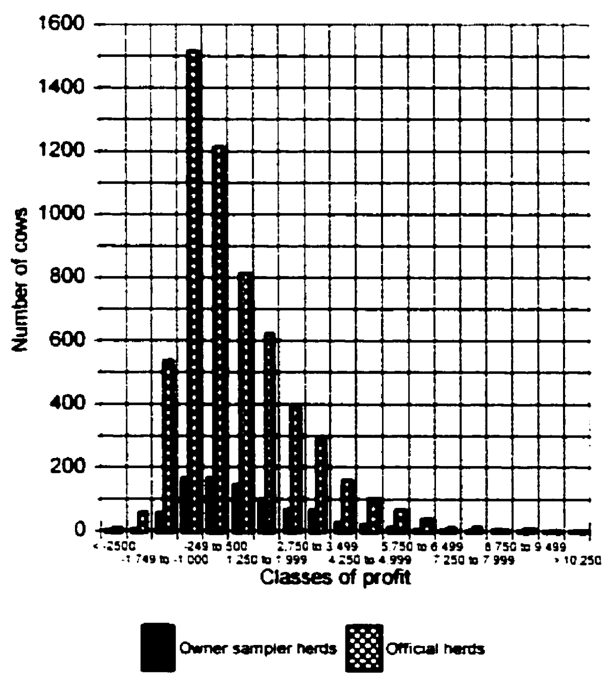


Figure 7.3 Distribution of lifetime profit adjusted for OC for Ayrshires

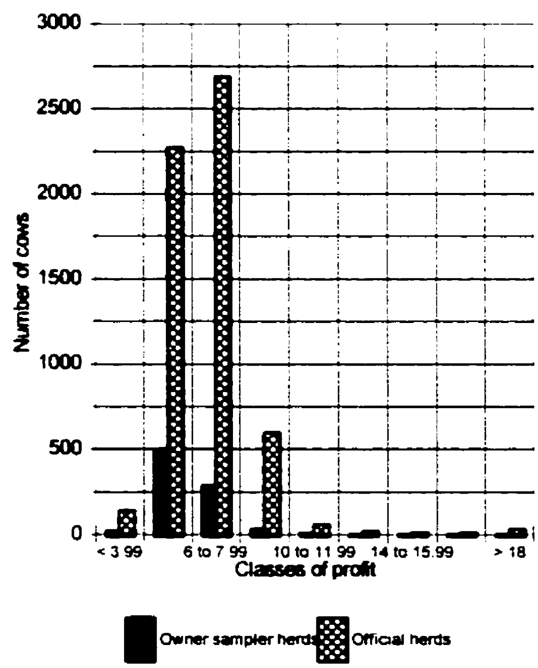


Figure 7.4 Distribution of profit per day for Ayrshires

4.3 Estimated breeding values

Figures 8.1 to 8.7 show the frequency distributions of Holstein cows per classes of estimated breeding values (EBV) of each trait. Figures A3 to A6 (in appendix) show the frequency distributions of Ayrshire, Jersey, Brown Swiss and Canadienne cows respectively. As expected, these distributions are normal. However, means of these 8 variables are not equal to zero. The deviation from zero could be explained by the differences that there were between the years when cows produced and the moment when genetic evaluations were obtained for these cows. Cows produced between 1980 and 1995, but genetic evaluations were those published in November 1999. From when the data were recorded to when genetic evaluations were obtained, genetically superior cows were born. The effect of this was to reduce the average of our cows born between 1980 to 1995 below zero.

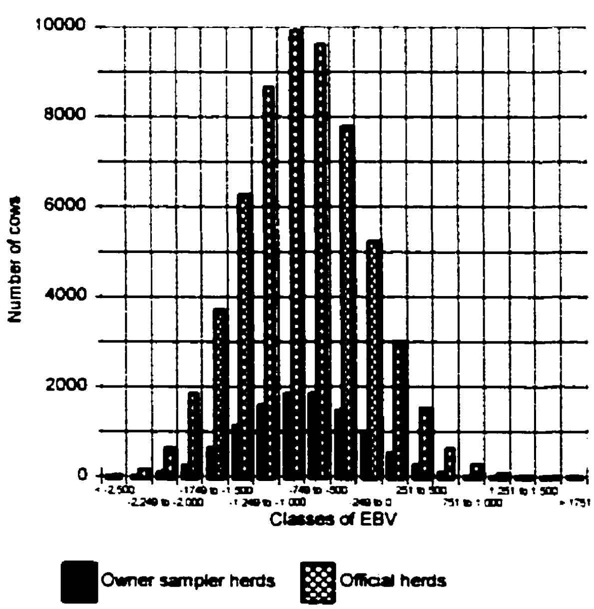


Figure 8.1 Distribution of EBV for milk production for Holstein

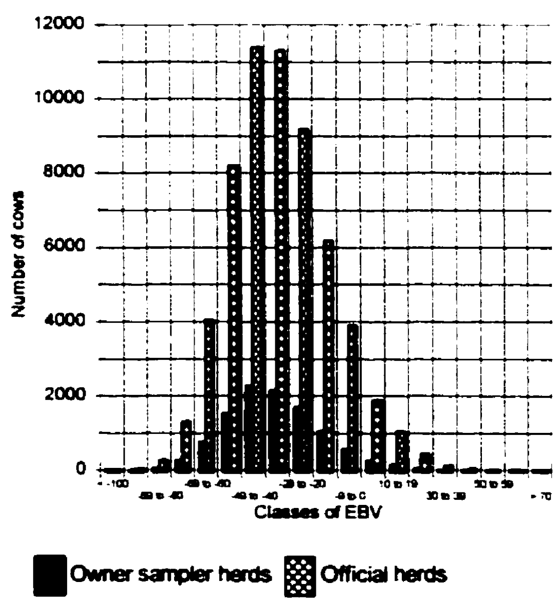


Figure 8.2 Distribution of EBV for fat production for Holstein

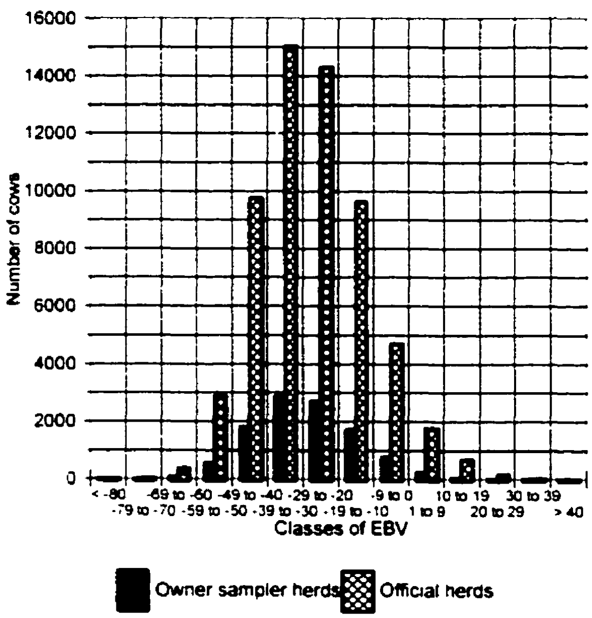


Figure 8.3 Distribution of EBV for protein production for Holstein

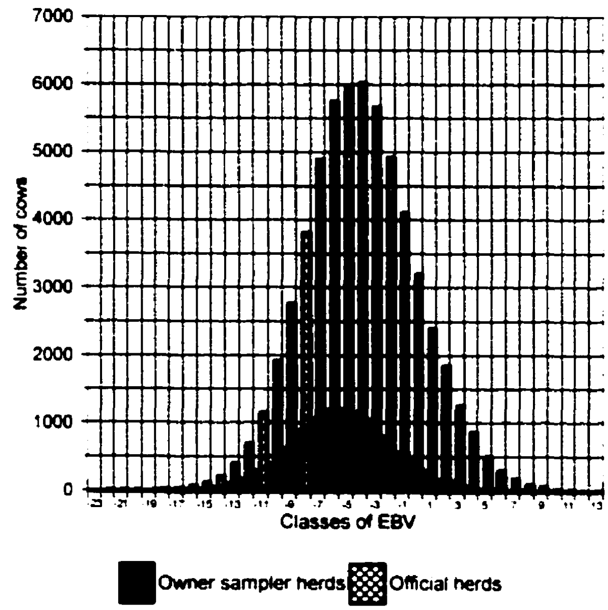


Figure 8.4 Distribution of EBV for conformation for Holstein

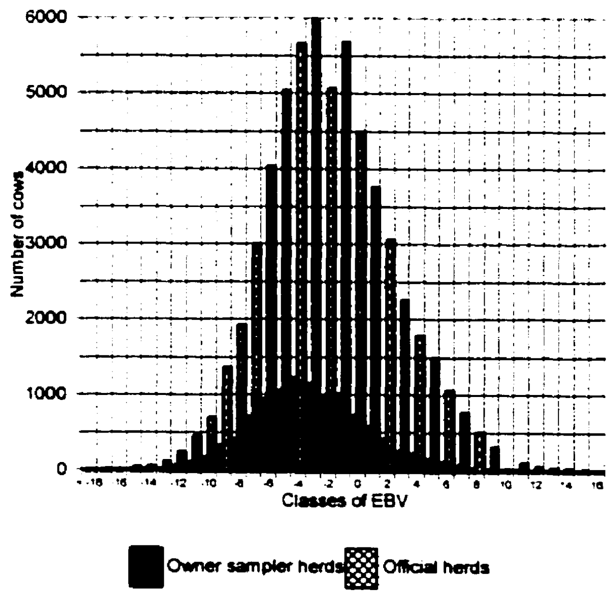


Figure 8.5 Distribution of EBV for capacity for Holstein

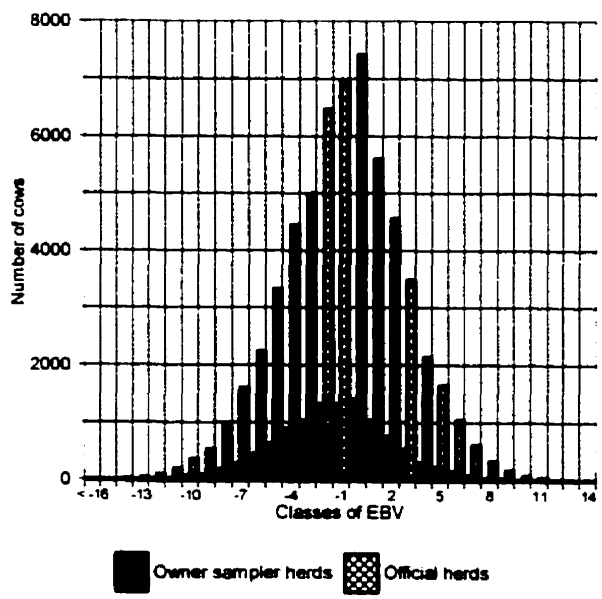


Figure 8.6 Distribution of EBV for feet and legs for Holstein

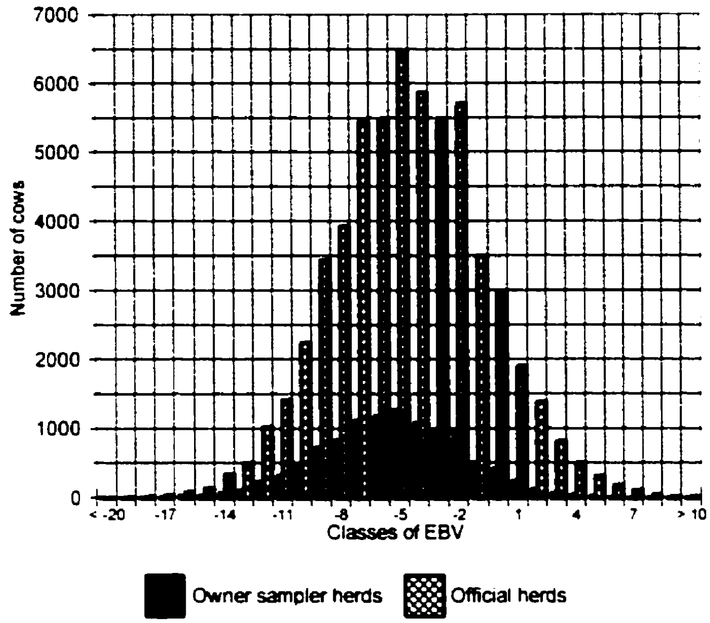


Figure 8.7 Distribution of EBV for mammary system for Holstein

4.4 Economic values of traits

4.4.1 Analysis of covariance strategy

An analysis of covariance model is a model that consists of both classification (qualitative) variables and continuous (quantitative) variables. Littell *et al.* (1996) described analysis of covariance as a methodology to compare a series of regression models. In this study, the qualitative variable was the recording option (official or owner sampler) and quantitative variables were genetic evaluations of traits. Separately for each breed, regression coefficients of traits were computed for both recording options. Then, the analysis of covariance model, allowed us to determine whether regression coefficients of a given trait were similar or different for the two recording options.

The strategy used to compute regression coefficients is similar to the one described by Littell *et al.* (1996). Three different models were used to determined whether regression coefficients of a given trait were different from one recording option to the other and whether each single regression coefficient was different from zero. These models are described in a simple form below:

Model 1 :

Profit = μ + herd-year-season(recording option) + $b_i \cdot$ recording option$_i$ + $b_j \cdot$ EBV trait$_j$ + $b_{ij} \cdot$ recording option$_i \cdot$ EBV trait$_j$ + e

where the effect of herd-year-season nested within recording program is random, $\mathbf{b_i}$ is the regression coefficient of the i^{th} recording option, $\mathbf{b_j}$ is the regression coefficient of the j^{th} trait and $\mathbf{b_{ij}}$ is the regression coefficient of the interaction effect between the j^{th} trait for cows and the i^{th} recording option. Both main effects - recording option and EBV of traits - were included as well as the interaction between these two effects. This model was used to verify if differences found between regression coefficients of the two recording options were statistically significant or not. In other words, this model verified if the interaction effect is significant, and consequently, if increases in genetic values of traits have the same effect on profit in both recording options.

Once established whether the same or two different regression coefficients must be used for the two recording options, models 2 and 3 were used to determine what these coefficients are and whether they are statistically significantly different from zero.

Model 2 :

Profit = μ + herd-year-season (recording option) + $b_i \cdot$ recording option$_i$ + $b_{ij} \cdot$ recording option$_i \cdot$ EBV trait$_j$ + e

where the effect of herd-year-season nested within recording program is random, b_i is the regression coefficient of the i^{th} recording option and b_{ij} is the regression coefficient (economic value) of the j^{th} trait for cows in the i^{th} recording option. This model contains only the recording option as a main effect and an interaction effect between the recording option and values of EBV for traits. The interaction effect yielded distinct regression coefficients of traits for the two recording options.

Model 3 :

Profit = μ + herd-year-season (recording option) + $b_i \cdot$ recording option$_i$

+ $b_j \cdot$ EBV trait$_j$ + e

where the effect of herd-year-season nested within recording program is random, b_i is the regression coefficient of the i^{th} recording option and b_j is the regression coefficient (economic value) of the j^{th} trait for cows in both recording options. No interaction effect is included in this model. Thus, model 3 yielded one single regression coefficient of each trait common to both recording options.

The herd-year-season effect was included in these three models to remove as much as possible management differences. Due to some computational limitations, genetic relationships among cows were not included in models. Residuals were plotted against fitted values and no particular pattern was found. It was thus appropriate to assume normality when analyses were performed. Non-linear relationships between traits and profit were not studied. It is known that some linear type traits have intermediate optimal scores. Classes of the four composite traits were plotted against profit, and relationships between the profit and each of these conformation traits were almost linear. Further analysis could be made to verify whether these relationship were statistically non-linear. Since quadratic terms are not included in selection indexes used in Canada, these kinds of analysis were not done in this project.

4.4.2 Lifetime profit

Economic values were first calculated by using lifetime profit as the dependant variable. Information on cows which calved for the first time between January 1980 and December 1989 were analysed in order to avoid the effect of truncation of data. A total of 70,100 Holstein, 7,181 Ayrshire, 235 Jersey, 73 Brown Swiss and 123 Canadienne lifetime records were analysed. Table 16 shows how many of these records come from owner sampler and official herds.

Before August 1992, the price for milk received by producers in Canada depended on the amount of milk and fat shipped. There was a price for one hectoliter of milk containing 3.6 kg of fat. Then, a differential was added or subtracted from this basic price for each 0.1

kg of fat over or under 3.6 (Bourbeau, 1992). Before August 1992, amount of protein shipped did not alter the price of milk. Therefore, protein was not included in this first analysis because it had no economic value before 1992.

Tables 17.1 to 17.5 show economic values of milk, fat and four traits related to the conformation of cows for each breed separately. These values are regression coefficients obtained by analysing models 2 or 3, explained above, with the MIXED procedure of SAS/STAT®. For each one unit increase in the genetic value of a given trait, lifetime profit will be increased by the value of the regression coefficient associated with this trait. When there was insufficient evidence to conclude slopes for owner-sampler and official herds were unequal, a pooled regression coefficient was computed.

Table 16: Number of lifetime records by breeds and recording options

Breed	Number of lifetime records			Number of herd-year-season		
	Owner Sampler herd	Official herd	Total	Owner Sampler herd	Official herd	Total
Holstein	**10,791**	**59,309**	**70,100**	**3,356**	**13,852**	**17,208**
Ayrshire	966	6,215	7,181	311	1,589	1,900
Jersey	**32**	**203**	**235**	**9**	**52**	**61**
Brown Swiss	17	56	73	6	20	26
Canadienne	**7**	**116**	**123**	**4**	**24**	**28**

Table 17.1: Economic values of milk, fat and type traits for Holstein cows using lifetime profit as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**1.92**	**0.12**	**2.42**	**0.05**	**----**	**----**
EBV fat	31.00	3.60	25.38	1.47	26.06	1.35
EBV conformation	**155.74**	**40.25**	**180.88**	**17.11**	**176.16**	**15.75**
EBV capacity	-102.69	18.37	-29.29	7.42	----	----
EBV feet and legs	**77.03**	**19.16**	**101.32**	**7.66**	**98.52**	**7.11**
EBV mamm. syst.	5.02^{NS}	33.31	50.87	13.96	45.03	12.88

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 17.2: Economic values of milk, fat and type traits for Ayrshire cows using lifetime profit as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**2.90**	**0.63**	**3.56**	**0.24**	**3.47**	**0.23**
EBV fat	36.10	17.83	34.37	6.82	34.59	6.37
EBV conformation	**231.15**	**87.32**	**311.71**	**32.42**	**300.14**	**30.35**
EBV capacity	-83.99^{NS}	79.59	-94.13	29.89	-92.91	27.97
EBV feet and legs	**40.70$^{N.S.}$**	**77.73**	**-26.77$^{N.S.}$**	**29.58**	**-15.42$^{N.S.}$**	**27.57**
EBV mamm. syst.	-156.16	75.40	-128.34	28.98	-134.08	27.00

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 17.3: Economic values of milk, fat and type traits for Jersey cows using lifetime profit as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**3.78^{NS}**	**2.82**	**4.94**	**1.21**	**4.96**	**1.07**
EBV fat	76.19^{NS}	78.99	17.60^{NS}	26.78	15.54^{NS}	24.36
EBV conformation	**16.33$^{N.S.}$**	**448.78**	**150.73$^{N.S.}$**	**153.57**	**167.53$^{N.S.}$**	**143.81**
EBV capacity	90.63^{NS}	559.75	31.49^{NS}	127.21	37.40^{NS}	121.72
EBV feet and legs	**-301.20$^{N.S.}$**	**335.73**	**447.74**	**147.75**	**----**	**----**
EBV mamm. syst.	-328.60^{NS}	427.35	-217.26^{NS}	136.87	-215.97^{NS}	130.58

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 17.4: Economic values of milk, fat and type traits for Brown Swiss cows using lifetime profit as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**16.57$^{N.S.}$**	**18.95**	**2.59$^{N.S.}$**	**3.65**	**2.01$^{N.S.}$**	**3.25**
EBV fat	-388.11^{NS}	483.46	9.23^{NS}	72.00	13.40^{NS}	66.89
EBV conformation	**307.61$^{N.S.}$**	**1,261.57**	**823.19**	**355.55**	**835.61**	**322.05**
EBV capacity	-515.76^{NS}	1,424.52	-930.24	371.04	-860.26	335.04
EBV feet and legs	**872.13$^{N.S.}$**	**1,214.18**	**-215.18$^{N.S.}$**	**307.11**	**-154.03$^{N.S.}$**	**251.75**
EBV mamm. syst.	-970.99^{NS}	900.49	5.74^{NS}	394.59	-129.24^{NS}	339.40

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 17.5: Economic values of milk and fat for Canadienne cows using lifetime profit as dependant variable*

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**-3.16^{NS}**	**4.53**	**1.94^{NS}**	**1.33**	**1.52^{NS}**	**1.28**
EBV fat	221.56^{NS}	137.33	52.75^{NS}	42.14	67.28^{NS}	40.21

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)
* No genetic evaluations are available for type traits

In the Holstein breed, a kilogram genetic increase in milk production had an economic value of 1.92$ for an owner sampler producer and 2.41$ for an officially supervised producer. Fat production had a larger effect on lifetime profits than milk production. A kilogram genetic increase in fat production had an economic value of 31.00$ and 25.38$ for an owner sampler and officially supervised producer, respectively. However, the difference found between the two recording options for the economic value of fat was not statistically significant. A pooled regression coefficient equal to 26.06$ per kg was computed. Increases in both milk and fat production had higher economic values in the Ayrshire breed than in the Holstein breed. A kilogram genetic increase in milk and fat production had economic values of 2.90$ and 36.10$ for owner sampler Ayrshire producers, respectively, and 3.56$ and 34.37$ for officially supervised Ayrshire producers respectively. Economic values found are higher than estimates reported by Gibson *et al.* (1992), but the pattern is similar: fat production affected more lifetime profits than milk production. Gibson *et al.* (1992) obtained lower economic values because all costs and returns used to compute economic values were calculated per year and their economic values (using the pricing system before 1992 in Canada) were equal to 0.1483 and 3.7376$ per kg of change in water and fat. Average marginal value of genetically increased output (returns minus costs) were computed to determine these values.

In the Jersey, Brown Swiss and Canadienne breeds, most of the traits obtained non-significant economic values. This is due to the low number of observations for these three breeds. A tendency, similar to that found for the Holstein and Ayrshire breeds, could be observed for production traits: a kilogram genetic increase in fat production had higher economic values than the same increase in milk production. However, most of these economic values were not significantly different from zero. It is, thus, difficult to conclude something precise from these results.

Since criteria used and scores attributed to cows for linear type traits vary from one breed to another, we cannot compare directly breeds for economic values related to conformation traits. However, some tendencies can be observed. In both Holstein and Ayrshire breeds, there were highly positive economic values attached to the genetic evaluations of conformation and negative economic values attached to the genetic evaluations of capacity. A unit genetic increase in conformation had a value of 176.16$ for Holstein producers and 300.14$ for Ayrshire producers (pooled regression coefficients). A unit genetic increase in capacity had a greater negative economic value for owner sampler Holstein producers than for officially supervised herds (-102.69$ vs -29.29$). In the Ayrshire breed, the pooled economic value attached to capacity was -92.91$. These results agree with what is reported in the literature. Several authors (i.e. De Haan *et al.*, 1992; Weigel *et al.*, 1995) have shown that conformation traits affect length of productive life and, consequently, lifetime profit of a cow. Final score of cows tended to be positively correlated to length of productive life, while stature and body depth (two linear type traits included in evaluation of capacity of cows in Canada) tended to have low or negative genetic correlations with number of months in milk through productive life of cows (De Haan *et al.*, 1992; Weigel *et al.*, 1995). Relationship between traits and length of productive life of cows differ between studies because they depend on how producers judge which cows must be culled. For example, in Canada, producers often prefer large cows, while in countries, such as New Zealand, where grass plays an important role, larger cows can be penalized. Economic values obtained in this study show that, even if producers prefer large cows and that capacity should be a good indicator of ability of cows in converting food, cows with higher score for this composite trait tend to have lower lifetime profit. Cows with a higher stature and weight tend to eat more and milk value does not seem to offset feed costs of larger cows.

A unit genetic increase in genetic evaluation for feet and legs had an economic value of 98.52$ for the Holstein breed and was not significant for the Ayrshire breed. Holstein cows tended to be heavier on average than Ayrshire cows. Increasing qualities of feet and legs help heavier cows to stand longer and avoid involuntary culling due to feet's problems. Holstein cows with a higher genetic value for feet and legs seem to live longer and have higher lifetime profits. The economic value attached to the genetic evaluation for the mammary system was negative (-134.08$) for Ayrshire cows and positive for Holstein cows (45.03$). For the Holstein breed, cows with a better mammary system probably produced more milk and for a longer time. This leads to higher lifetime profit. For the Ayrshire breed, it is difficult to explain why cows with a higher genetic evaluation for mammary system tended to have lower lifetime profit. It may be that increases in milk production, resulting from better mammary systems, were offset by increases in feed requirements to produce this milk.

4.4.3 Profit until the end of the fifth lactation

Profit until the end of the fifth lactation was chosen as a profitability measurement to reflect the situation that the selection index, called Total Economic Value (TEV), attempts to illustrate. Tables 18.1 to 18.5 show, for each breed separately, economic values of milk, fat and four traits related to the conformation of cows computed by using profit until the end of the fifth lactation as the dependant variable. Since only a small proportion of cows produced more than 5 lactations, results shown in table 18 are similar to those obtained by using lifetime profits. Numbers of observations which were analysed to obtain these economic values are shown in table 16.

A kilogram genetic increase in milk and fat productions tended to have higher economic values for both Holstein and Ayrshire breeds and testing programs than economic values obtained by using lifetime profits. An increase in milk and fat production had respective values of 1.71$ and 35.57$ for owner sampler Holstein producers, 2.05$ and 28.45$ for officially supervised Holstein producers, and 2.88$ and 40.00$ for Ayrshire producers. Economic values of production traits computed for the Jersey, Brown Swiss and Canadienne breeds were still not significantly different from zero except for one trait: a unit genetic increase in milk production for the Jersey breed obtained a value of 4.06$.

Table 18.1: Economic values of milk, fat and type traits for Holstein cows using profit until the end of fifth lactation as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**1.71**	**0.10**	**2.05**	**0.04**	----	----
EBV fat	35.57	2.78	28.45	1.13	----	----
EBV conformation	**129.40**	**31.16**	**156.04**	**13.26**	**151.31**	**12.20**
EBV capacity	-73.93	14.21	-22.68	5.75	----	----
EBV feet and legs	**43.01**	**14.82**	**66.80**	**5.94**	**63.89**	**5.51**
EBV mamm. syst.	2.40^{NS}	25.78	22.34	10.82	20.03	9.98

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 18.2: Economic values of milk, fat and type traits for Ayrshire cows using profit until the end of fifth lactation as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**2.36**	**0.49**	**2.96**	**0.19**	**2.88**	**0.18**
EBV fat	40.07	13.80	39.86	5.29	40.00	4.93
EBV conformation	**178.91**	**67.59**	**218.00**	**25.13**	**212.28**	**23.52**
EBV capacity	-71.13^{NS}	61.63	-59.86	23.16	-61.48	21.67
EBV feet and legs	**31.61^{NS}**	**60.17**	**-8.23^{NS}**	**22.92**	**-1.86^{NS}**	**21.36**
EBV mamm. syst.	-94.45^{NS}	58.35	-102.00	22.45	-102.16	20.92

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 18.3: Economic values of milk, fat and type traits for Jersey cows using profit until the end of fifth lactation as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**3.57^{NS}**	**2.30**	**3.90**	**0.98**	**4.06**	**0.87**
EBV fat	42.62^{NS}	63.98	29.60^{NS}	21.70	24.17^{NS}	19.69
EBV conformation	**41.98^{NS}**	**366.88**	**50.42^{NS}**	**125.09**	**72.81^{NS}**	**116.86**
EBV capacity	237.54^{NS}	456.54	88.25^{NS}	103.64	98.65^{NS}	98.92
EBV feet and legs	**-285.06^{NS}**	**273.57**	**327.05**	**120.17**	**----**	**----**
EBV mamm. syst.	-186.26^{NS}	349.35	-126.58^{NS}	111.42	-128.49^{NS}	106.00

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 18.4: Economic values of milk, fat and type traits for Brown Swiss cows using profit until the end of fifth lactation as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**14.43^{NS}**	**14.72**	**3.74^{NS}**	**2.83**	**3.10^{NS}**	**2.52**
EBV fat	-328.37^{NS}	375.91	-10.89^{NS}	55.84	-7.65^{NS}	52.04
EBV conformation	**132.37^{NS}**	**969.36**	**690.45**	**275.02**	**705.80**	**250.48**
EBV capacity	-473.89^{NS}	1,102.92	-884.24	287.34	-841.51^{NS}	260.63
EBV feet and legs	**820.15^{NS}**	**944.32**	**-79.42^{NS}**	**237.17**	**-51.58^{NS}**	**195.78**
EBV mamm. syst.	-755.42^{NS}	693.21	104.12^{NS}	305.15	-35.90^{NS}	263.96

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 18.5: Economic values of milk and fat for Canadienne cows using profit until the end of the fifth lactation as dependant variable for the Canadienne breed

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**-3.15^{NS}**	**4.30**	**1.83^{NS}**	**1.26**	**1.42^{NS}**	**1.21**
EBV fat	222.32^{NS}	130.58	52.30^{NS}	40.06	66.98^{NS}	38.26

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

* No genetic evaluations are available for type traits

Compared to economic values obtained by using lifetime profit [see section 4.4.2], in this study of profit until the end of the 5th lactation, type traits lost some of their economic worth. Truncating profits after the end of the fifth lactation reduced the opportunity for cows which have the ability to produce for a longer time to display their superiority. Cows that produce on average for a longer period of time probably have on average higher lifetime profit. When profit until the end of the fifth lactation was used, all cows were judged only on their five first lactations and effects of better conformation traits on longevity were diminished.

4.4.4 Lifetime profit adjusted for opportunity cost of postponed replacement

Lifetime profits adjusted for OC of postponed replacement of cows were also used as the dependant variable to compute other sets of economic values. Table 19 shows how many observations were analysed while tables 20.1 through 20.5 show, for each breed, economic values of milk, fat and conformation traits.

Once again, a kilogram genetic increase in fat production had economic values higher than a kilogram genetic increase in milk production. Pooled economic values attached to fat production were equal to 21.14$ and 34.59$ in the Holstein and Ayrshire breeds, respectively, while economic values attached to milk production were equal to 0.88$ for owner sampler Holstein producers, 0.97$ for officially supervised Holstein producers and 1.49$ for Ayrshire producers. This trend is also noticed in the Jersey, Brown Swiss and Canadienne breeds. However, in these breeds, all economic values attached to production traits were still not significant except one: a kilogram genetic increase in milk production had a value of 2.17$ for Jersey producers.

A unit increase in conformation traits had much lower economic values in Holstein and Ayrshire breeds than in the two previous analyses which used non-adjusted lifetime profits and profits until the end of fifth lactation as dependant variables. For example, a unit genetic increase in the genetic evaluation of the composite trait final score (conformation) had a economic value of 176.16$ for Holstein producers when non-adjusted lifetime profits were used, 151.31$ when profits until the end of fifth lactation were used and 27.51$ when lifetime profits adjusted for OC were used. The same trend occurred for other conformation traits in the Holstein breed: economic values attached to capacity were less negative than in the two previous analyses in both recording options; economic values attached to feet and legs decreased and finally economic values attached to mammary system, which were slightly positive in the two first analysis, became not significantly different from zero. These results are consistent with the effects of adjusting lifetime profit for OC of postponed replacement reported in the literature. Van Arendonk (1991) found that adjusting lifetime profits for OC reduced the regression coefficient computed for herd life, which is correlated with type traits, without modifying the regression coefficient computed for milk production. De Haan *et al.* (1992) also concluded that adjustment of lifetime profit reduces the influence of type traits.

Table 19: Number of lifetime records by breed and recording option

Breed	Number of lifetime records			Number of herd-year-season		
	Owner Sampler herd	Official herd	Total	Owner Sampler herd	Official herd	Total
Holstein	**9,794**	**56,276**	**66,070**	**3,353**	**14,797**	**18,150**
Ayrshire	837	5,837	6,674	309	1,651	1,960
Jersey	**23**	**180**	**203**	**7**	**47**	**54**
Brown Swiss	14	44	58	6	19	25
Canadienne	**7**	**114**	**121**	**4**	**24**	**28**

Table 20.1: Economic values of milk, fat and type traits for Holstein cows using lifetime profit adjusted for OC of postponed replacement as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.88**	**0.04**	**0.97**	**0.02**	**----**	**----**
EBV fat	23.04	1.19	20.86	0.47	21.14	0.44
EBV conformation	**37.06**	**13.12**	**26.02**	**5.48**	**27.51**	**5.05**
EBV capacity	-35.28	6.01	-20.72	2.39	----	----
EBV feet and legs	**21.40**	**6.27**	**26.14**	**2.47**	**25.56**	**2.30**
EBV mamm. syst.	-16.89^{NS}	10.89	5.99^{NS}	4.49	2.86^{NS}	4.15

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 20.2: Economic values of milk, fat and type traits for Ayrshire cows using lifetime profit adjusted for OC of postponed replacement as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**1.53**	**0.23**	**1.47**	**0.09**	**1.49**	**0.08**
EBV fat	29.30	6.67	26.66	2.44	26.91	2.29
EBV conformation	**36.51^{NS}**	**31.92**	**49.92**	**11.52**	**48.16**	**10.82**
EBV capacity	-6.75^{NS}	29.36	-10.91^{NS}	10.62	-10.27^{NS}	9.98
EBV feet and legs	**9.26^{NS}**	**27.97**	**-1.36^{NS}**	**10.51**	**0.12^{NS}**	**9.81**
EBV mamm. syst.	-15.66^{NS}	28.70	-9.66^{NS}	10.38	-10.42^{NS}	9.74

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 20.3: Economic values of milk, fat and type traitsfor Jersey cows using lifetime profit adjusted for OC of postponed replacement as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**1.97^{NS}**	**1.72**	**2.02**	**0.60**	**2.17**	**0.56**
EBV fat	56.95^{NS}	45.97	15.71^{NS}	13.43	11.33^{NS}	12.43
EBV conformation	**73.28^{NS}**	**287.09**	**30.33^{NS}**	**76.50**	**36.26^{NS}**	**73.79**
EBV capacity	265.53^{NS}	329.91	129.84	65.65	143.97	63.79
EBV feet and legs	**-509.00**	**237.84**	**169.20**	**75.27**	**----**	**----**
EBV mamm. syst.	-286.31^{NS}	277.19	-123.24^{NS}	69.56	-125.61^{NS}	67.48

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 20.4: Economic values of milk, fat and type traits for Brown Swiss cows using lifetime profit adjusted for OC of postponed replacement as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**9.83^{NS}**	**8.23**	**0.60^{NS}**	**1.50**	**0.49^{NS}**	**1.34**
EBV fat	-240.12^{NS}	212.85	47.19^{NS}	30.48	43.29^{NS}	28.63
EBV conformation	**341.16^{NS}**	**570.87**	**204.51^{NS}**	**155.24**	**225.04^{NS}**	**141.38**
EBV capacity	-1,312.35^{NS}	847.42	-179.25^{NS}	178.46	-211.88^{NS}	163.39
EBV feet and legs	**638.15^{NS}**	**520.10**	**-117.97^{NS}**	**131.04**	**-118.13^{NS}**	**108.99**
EBV mamm. syst.	224.34^{NS}	466.88	-54.31^{NS}	175.97	-59.92^{NS}	152.69

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 20.5: Economic values of milk and fat for Canadienne cows using lifetime profit adjusted for OC of postponed replacement as dependant variable*

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**-1.18^{NS}**	**2.53**	**1.58**	**0.78**	**1.33^{NS}**	**0.74**
EBV fat	93.60^{NS}	78.05	21.38^{NS}	25.07	28.08^{NS}	23.80

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

* No genetic evaluations are available for type traits

In the Ayrshire breed, the trait conformation obtained a pooled significant economic value equal to 48.16$, however all other type traits in both recording options obtained nonsignificant economic values. This means these other traits (capacity, feet and legs and mammary system) did not help to explain the variability observed in lifetime profits. In the Jersey, Brown Swiss and Canadienne breeds, standard errors of economic values attached to type traits were, again, too high to attempt to draw any conclusions.

4.4.5 Profit per day of herd life

Finally, profits per day of herd life were used to compute economic values. Tables 21.1 through 21.5 show, for each breed separately, economic values of milk, fat and four type traits. All values shown in tables 21.1 to 21.5 are expressed in cents for clarity. Numbers of observations, which were analysed to obtain these economic values, are the same as those shown in table 19.

As for the other profitability measures, a kilogram genetic increase in fat production had a higher economic value than an increase in milk production. Economic values for milk production were equal to 0.05¢ in both Holstein and Ayrshire breeds and not statistically significant in Jersey, Brown Swiss and Canadienne breeds. Economic values attached to fat production were equal to about 2.50¢ per day for Holstein and Ayrshire producers, about 3.00¢ per day for Jersey and Brown Swiss producers, and about 5.21¢ (not significant) for Canadienne producers.

Table 21.1: Economic values of milk, fat and type traits for Holstein cows using profit per day (×100) as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.06**	**0.005**	**0.05**	**0.002**	**0.05**	**0.002**
EBV fat	2.34	0.16	2.58	0.06	2.55	0.06
EBV conformation	**-0.82^{NS}**	**1.75**	**-1.63**	**0.73**	**-1.51**	**0.67**
EBV capacity	-1.27^{NS}	0.80	-0.92	0.32	-0.97	0.29
EBV feet and legs	**-0.39^{NS}**	**0.84**	**0.68**	**0.33**	**0.53^{NS}**	**0.31**
EBV mamm. syst.	1.34^{NS}	1.45	0.96^{NS}	0.60	1.01^{NS}	0.55

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 21.2: Economic values of milk, fat and type traits for Ayrshire cows using profit per day (×100) as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.03^{NS}**	**0.03**	**0.06**	**0.01**	**0.05**	**0.01**
EBV fat	2.65	0.83	2.47	0.30	2.50	0.28
EBV conformation	**-0.92^{NS}**	**3.97**	**-2.51^{NS}**	**1.41**	**-2.32^{NS}**	**1.33**
EBV capacity	3.44^{NS}	3.64	0.33^{NS}	1.31	0.70^{NS}	1.23
EBV feet and legs	**-1.85^{NS}**	**3.48**	**0.04^{NS}**	**1.30**	**-0.19^{NS}**	**1.21**
EBV mamm. syst.	2.92^{NS}	3.57	4.31	1.28	4.17	1.20

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 21.3: Economic values of milk, fat and type traits for Jersey cows using profit per day (×100) as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.01^{NS}**	**0.13**	**0.02^{NS}**	**0.05**	**0.02^{NS}**	**0.04**
EBV fat	2.20^{NS}	3.45	3.18	1.01	3.09	0.91
EBV conformation	**4.39^{NS}**	**21.67**	**1.06^{NS}**	**5.77**	**1.20^{NS}**	**5.42**
EBV capacity	1.41^{NS}	24.86	6.95^{NS}	4.95	6.85^{NS}	4.68
EBV feet and legs	**-0.22^{NS}**	**17.90**	**4.32^{NS}**	**5.67**	**3.79^{NS}**	**5.29**
EBV mamm. syst.	-14.40^{NS}	20.91	-10.91	5.24	-11.18	4.95

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 21.4: Economic values of milk, fat and type traits for Brown Swiss cows using profit per day (×100) as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.31^{NS}**	**0.45**	**0.03^{NS}**	**0.06**	**0.03^{NS}**	**0.06**
EBV fat	-5.10^{NS}	12.21	3.39	1.32	2.97	1.33
EBV conformation	**26.12^{NS}**	**22.44**	**0.50^{NS}**	**6.85**	**6.00^{NS}**	**6.57**
EBV capacity	-43.19^{NS}	35.60	4.74^{NS}	8.14	-1.90^{NS}	7.84
EBV feet and legs	**3.43^{NS}**	**27.17**	**5.86^{NS}**	**5.47**	**-0.78^{NS}**	**4.80**
EBV mamm. syst.	1.17^{NS}	21.24	-2.68^{NS}	7.84	-4.82^{NS}	7.29

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 21.5: Economic values of milk and fat for Canadienne cows using profit per day (×100) as dependant variable

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.08^{NS}**	**0.31**	**-0.12^{NS}**	**0.09**	**-0.10^{NS}**	**0.09**
EBV fat	-1.07^{NS}	9.22	5.86^{NS}	2.97	5.21^{NS}	2.81

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

* No genetic evaluations are available for type traits

A unit increase in every conformation trait had low or non-significant economic value. Surprisingly, negative economic values were attached to the trait conformation in the Holstein and Ayrshire breeds (although not significant in the Ayrshire breed). This means that cows with higher EBVs for this trait had lower values of profit per day. The conformation of a cow, as already mentioned, is positively correlated to her longevity. Cows with a high EBV for the trait conformation seemed to have larger lifetime profit. To compute profit per day, lifetime profits were divided by the number of days between the first calving and the culling date. Cows who lived longer probably had, on average, a lower profit per day because, by the end of their productive live, their profitability decreased. This could explain negative economic values attached to the trait conformation in both Holstein and Ayrshire breeds.

4.4.6 Lactation profit

Lactation profits were used to examine consequences of a change in the pricing system. In Quebec, the pricing system was changed in August 1992. Before this modification, prices received by producers for their milk depended on the amount of milk and fat shipped. At the beginning of 90's, this pricing system was revised to take into account the evolution of consumers demand. Fat received bad publicity and protein became more popular. Since August 1992, protein and lactose have been included in the calculation of the milk price.

The deletion of lactations which began after the end of 1994 caused what is called a truncation effect (see figure 4). As explained previously, average lifetime profit of cows which calved for the first time between 1990 and 1994 are biased. Some cows were eliminated from the data set just because they produced and/or were culled outside the range 1980-1994.

Moreover, these eliminated cows were probably those with higher lifetime profits because they had longer productive lives. Profits of the first complete lactation of cows which calved between August 1992 and December 1994 were thus more representative than lifetime profits for this specific period. To contrast sets of economic values computed for this group of cows, we used profits of the first complete lactation of cows which calved between January 1980 and December 1988. Tables 22 to 24 show results obtained in the Holstein, Ayrshire and Jersey breeds respectively. Tables 25 and 26 show how many observations were analysed to obtain these sets of economic values.

No results are shown for the Brown Swiss and Canadienne breeds because the numbers of observations available were too low. In the three other breeds, similar results were obtained. Economic values attached to the milk and fat productions decreased or remained statistically at the same level. Between 1980 and 1988, a kilogram genetic gain in milk and fat production increased profits in the first lactation by 0.29$ and 8.10$ respectively for owner sampler Holstein producers, by 0.39$ and 9.88$ for officially supervised Holstein producers and by 0.47$ and 12.05$ for Ayrshire producers. After August 1992, a similar gain in milk and fat production caused smaller increases in profits of the first lactation except for owner sampler Holstein producers for who the economic value attached to fat production remained statistically at the same level.

Economic values attached to protein production changed drastically after August 1992. A kilogram genetic increase in protein production had negative economic values between 1980 and 1988 in both Holstein and Ayrshire breeds because no direct return was associated with protein production in the old pricing system. Producers had to indirectly pay to produce this protein, even if it did not modify the milk price. As expected, between August 1992 and December 1994, a kilogram genetic increase in protein production had a positive economic value. This increase altered profits of the first lactation positively because, in the new pricing system, protein production has a real economic value. The pooled economic value attached to the protein production for Holstein producers was equal to -3.70$ before 1989 and to 7.50$ after August 1992.

Table 22.1: Economic values of milk, fat, protein and type traits computed by using first lactation profit as dependant variable for Holstein cows, which calved for the first time between January 1980 and December 1988

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.29**	**0.02**	**0.39**	**0.01**	----	----
EBV fat	8.10	0.51	9.88	0.21	----	----
EBV protein	**-2.89**	**0.99**	**-3.84**	**0.40**	**-3.70**	**0.37**
EBV conformation	4.72^{NS}	4.56	4.75	1.93	4.68	1.78
EBV capacity	**-6.39**	**2.11**	**-4.60**	**0.86**	**-4.79**	**0.79**
EBV feet and legs	-3.95^{NS}	2.20	-2.04	0.88	-2.27	0.82
EBV mamm. syst.	**1.26^{NS}**	**3.77**	**2.57**	**1.57**	**2.44**	**1.45**

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 22.2: Economic values of milk, fat, protein and type traits computed by using first lactation profit as dependant variable for Holstein cows, which calved for the first time between August 1992 and December 1994

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.09**	**0.02**	**0.13**	**0.01**	**0.12**	**0.01**
EBV fat	8.24	0.39	8.43	0.24	8.39	0.20
EBV protein	**7.06**	**0.85**	**7.57**	**0.53**	**7.50**	**0.45**
EBV conformation	14.38	4.24	16.16	2.91	15.40	2.39
EBV capacity	**-8.79**	**1.89**	**-5.86**	**1.20**	**-6.69**	**1.01**
EBV feet and legs	-10.44	1.92	-12.40	1.22	-11.80	1.03
EBV mamm. syst.	**-10.57**	**3.43**	**-14.19**	**2.28**	**-12.97**	**1.89**

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 23.1: Economic values of milk, fat, protein and type traits computed by using first lactation profit as dependant variable for Ayrshire cows, which calved for the first time between January 1980 and December 1988

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**0.46**	**0.09**	**0.47**	**0.03**	**0.47**	**0.03**
EBV fat	8.59	2.94	12.40	1.00	12.05	0.94
EBV protein	**-10.96**	**4.19**	**-7.89**	**1.44**	**-8.33**	**1.36**
EBV conformation	-1.62^{NS}	11.03	-2.83^{NS}	3.72	-2.64^{NS}	3.52
EBV capacity	**8.58^{NS}**	**10.53**	**2.82^{NS}**	**3.52**	**3.17^{NS}**	**3.34**
EBV feet and legs	1.93^{NS}	10.30	7.57	3.47	7.02	3.28
EBV mamm. syst.	**2.29^{NS}**	**10.51**	**-5.41^{NS}**	**3.63**	**-4.75^{NS}**	**3.43**

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 23.2: Economic values of milk, fat, protein and type traits computed by using first lactation profit as dependant variable for Ayrshire cows, which calved for the first time between August 1992 and December 1994

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**-0.09^{NS}**	**0.10**	**0.07^{NS}**	**0.05**	**0.04^{NS}**	**0.04**
EBV fat	9.64	2.40	7.84	1.18	8.27	1.06
EBV protein	**14.93**	**4.14**	**12.48**	**1.95**	**12.83**	**1.76**
EBV conformation	6.11^{NS}	12.36	27.85	6.69	23.11	5.87
EBV capacity	**3.62^{NS}**	**7.65**	**-2.69^{NS}**	**4.29**	**-1.35^{NS}**	**3.73**
EBV feet and legs	-3.97^{NS}	8.22	-11.00	4.10	-9.55	3.66
EBV mamm. syst.	**-11.82^{NS}**	**8.69**	**-20.73**	**4.64**	**-18.64**	**4.08**

^{NS} means this coefficient of regression is not statistically different from zero (P > 0.05)

Table 24.1: Economic values of milk, fat, protein and type traits computed by using first lactation profit as dependant variable for Jersey cows, which calved for the first time between January 1980 and December 1988

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**-0.68^{NS}**	**0.65**	**0.97**	**0.28**	**----**	**----**
EBV fat	-14.03^{NS}	23.46	15.03	6.97	10.48^{NS}	6.57
EBV protein	**55.07^{NS}**	**42.40**	**-25.76**	**11.41**	**-17.96^{NS}**	**10.80**
EBV conformation	10.73^{NS}	89.09	-24.31^{NS}	23.95	-15.76^{NS}	22.15
EBV capacity	**8.79^{NS}**	**101.45**	**20.18^{NS}**	**18.81**	**18.83^{NS}**	**18.09**
EBV feet and legs	-38.15^{NS}	73.07	35.88^{NS}	24.21	19.42^{NS}	21.84
EBV mamm. syst.	**-91.06^{NS}**	**82.51**	**8.04^{NS}**	**21.04**	**5.13^{NS}**	**20.12**

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 24.2: Economic values of milk, fat, protein and type traits computed by using first lactation profit as dependant variable for Jersey cows, which calved for the first time between August 1992 and December 1994

Effect	Owner-Sampler herds		Official herds		Pooled	
	Regression coefficient	s.e.	Regression coefficient	s.e.	Regression coefficient	s.e.
EBV milk	**-0.10^{NS}**	**0.92**	**0.25^{NS}**	**0.26**	**0.23^{NS}**	**0.24**
EBV fat	3.31^{NS}	15.15	4.45^{NS}	4.38	4.50^{NS}	4.12
EBV protein	**12.02^{NS}**	**38.30**	**6.88^{NS}**	**10.24**	**6.96^{NS}**	**9.74**
EBV conformation	76.12^{NS}	74.61	-2.02^{NS}	23.39	5.34^{NS}	21.78
EBV capacity	**-27.40^{NS}**	**40.93**	**-0.96^{NS}**	**13.61**	**-2.76^{NS}**	**12.34**
EBV feet and legs	-28.96^{NS}	49.98	0.98^{NS}	18.00	-4.16^{NS}	16.60
EBV mamm. syst.	**-41.19^{NS}**	**77.86**	**11.67^{NS}**	**21.30**	**6.73^{NS}**	**20.20**

^{NS} means this coefficient of regression is not statistically different from zero ($P > 0.05$)

Table 25: Number of lactation records between January 1980 and December 1988 by breed and recording option

Breed	Number of lactation records			Number of herd-year-season		
	Owner Sampler herd	Oficial herd	Total	Owner Sampler herd	Oficial herd	Total
Holstein	**8,768**	**46,343**	**55,111**	**2,837**	**11,027**	**13,864**
Ayrshire	633	4.756	5.389	225	1.272	1.497
Jersey	**17**	**83**	**100**	**5**	**22**	**27**

Table 26: Number of lactation records between August 1992 and December 1994 by breed and recording option

Breed	Number of lactation records			Number of herd-year-season		
	Owner Sampler herd	Oficial herd	Total	Owner Sampler herd	Oficial herd	Total
Holstein	**14,071**	**35,155**	**49,226**	**3,574**	**7,000**	**10,574**
Ayrshire	886	3.128	4.014	219	682	901
Jersey	**37**	**260**	**297**	**5**	**53**	**58**

For Ayrshire producers, the economic value attached to the same trait increased from -8.33$ before 1989 to +12.83$ after August 1992. In the Jersey breed, values computed were not statistically significantly, however the same tendency as for the two other breeds was found.

Similar results were found by Gibson *et al.* (1992). They derived economic values for a variety of production circumstances and they concluded that changes in pricing of milk caused the largest modifications in economic values. When the volume payment with fat correction was used, economic values obtained for the fat and protein productions were respectively equal to 3.73 and -0.49$ per kg. When the multiple-component pricing system, in which prices are assigned for volume, fat, protein and lactose in milk, was used, economic values obtained for fat and protein production were respectively equal to 3.08 and 3.62$ per kg. Of course, as the price for protein increased and price for fat decreased, and economic values of protein and fat respectively increased and decreased.

4.4.7 Economic values used around the world

Table 27 shows, where available, economic values and selection indexes used in six different countries. Both vary from one country to another because payment and quota systems utilized are different. However, a tendency can be noticed. In all countries shown in table 27, the index coefficient of protein production is always higher than the coefficient of milk and fat productions. All indexes presented in table 27 have a slightly negative weighting on milk. Thus, the trend observed for production traits in results found in this study agree with selection criteria used in other countries, such as Australia, the United Kingdom and the United States. Since August 1992, protein has been the most economically important production trait in Quebec and milk has a economic importance near zero.

Selection index formulae used in New Zealand are not directly available on the AEU web site (AEU, 2000), but economic values used in 2000 to compute these indexes are available in NZ$. The economic importance of protein is again illustrated. It is also interesting to note that economic value of liveweight is negative. In New Zealand, grass is very important and large cows are economically undesirable. In United-States, even if, in some part of this country, milk production is not as much grass oriented, a negative weight on size of animals is included in the selection index. It would be interesting to compute breeding values for body weight of cows included in analyses presented in the study described in this thesis to be able to obtain economic values for this trait. The trait capacity gives an idea of how the stature of animals affects profit on average. However, by using the genetic evaluation of body weight directly, the question as to whether larger cows are really more profitable could be answered. This analysis was not performed due to some computational and time limitations. Conformation traits, when included in indexes, are associated with notable coefficients. However, as explained earlier for the different breeds, criteria used in countries to evaluate the animals' conformation differ. It is thus difficult and, perhaps, impossible to contrast index coefficients of conformation traits.

Table 27: Economic values and selection indexes used in other countries

Country	Economic Values	Selection Index
Germany (VIT Informations-systeme Tierhaltung, 2000)	Relative economic values: • Production traits: 56% • Conformation traits: 20% • Somatic Cell Score: 14% • Reproduction (calving ease, stillbirth, fertility, functional herdlife): 10%	RZG = 100 + 0.88 (Prod. traits - 100) + 0.36 (Conf. traits - 100) + 0.22 (Som. cell score - 100) + 0.16 (Reproduction - 100)
Australia **(ADHIS, 2000)**	N/A	**ASI = (3 × Protein BV) + Fat BV - (0.03 × Milk BV)** **Type breeding values, workability breeding values and survival breeding value are also computing and used as secondary criteria for selection**
New Zealand (AEU, 2000)	Economic values used for BW: • Milk fat: 1.177 NZ$/kg • Protein: 3.503 NZ$/kg • Milk: -0.049 NZ$/ltr • Liveweight: -0.487 NZ$/kg • Longevity: 0.029 NZ$/day Economic values used for PW • Milk fat: 1.516 NZ$/kg • Protein: 4.074 NZ$/kg • Milk: -0.059 NZ$/ltr • Liveweight: -0.600 NZ$/kg Economic values used for LW • Milk fat: 1.967 NZ$/kg • Protein: 4.801 NZ$/kg • Milk: -0.069 NZ$/ltr • Liveweight: -0.727 NZ$/kg	Three indexes: *BW* measures the expected ability of the cow to breed replacements which are efficient converters of feed into profit. *PW* measures the ability of the cow to convert feed into profit over her lifetime. *LW* measures the expected ability of the cow to convert feed into profit in the current season.

Table 27 (continued): Economic values and selection indexes used in other countries

Country	Economic Values	Selection Index
United Kingdom (Animal Data Centre, 2000a) (Animal Data Centre, 2000b)	N/A	£PIN = Production Profit Index = (Milk kg PTA × -0.03) + (Fat kg PTA × 0.50) + (Protein kg PTA × 3.00) £PLN = Profitable Life Index = (Milk kg PTA × -0.03) + (Fat kg PTA × 0.50) + (Protein kg PTA × 3.00) + (Lifespan PTA × 28)
United States **(USDA, 2000)**	**Same as Index coefficients**	**Lifetime Net Merit =** $(0.018 \times PTA_{milk}) + (2.14 \times PTA_{fat})$ $+ (4.76 \times PTA_{protein})$ $+ (28 \times PTA_{prod\ life}) + (-154 \times PTA_{SCS})$ $+ (-14 \times PTA_{size}) + (29 \times PTA_{udder})$ $+ (15 \times PTA_{fl})$

V. Conclusion

In the present study, field recorded data were used to compute economic values of traits for dairy cattle improvement. To provide empirical economic values, PATLQ records were used to regress profitability measurements on estimated breeding values of traits obtained from the Canadian Dairy Network. Five different profitability measurements were first computed: lifetime profit, profit until the end of the fifth lactation, lifetime profit adjusted for opportunity cost of postponed replacement, profit per day of productive life and first lactation profit. Each of these measurements were used as the dependent variable in a covariance model. This yielded different sets of economic values for each breed and testing program (Official and owner-sampler). It has been shown that before 1990, economic values attached to milk production were small and positive, and that a kilogram genetic increase in fat production had significantly larger economic value than the similar increase in milk production. For most breeds and testing programs, economic values attached to the trait called conformation were highly positive and economic values attached to the trait called capacity were negative. This indicates that an unit genetic increase in conformation affects profitability measurements positively and a similar increase in capacity tends to decrease the profit of cows. Capacity of cows is related to the stature and the size of the animal. Results found in this study have shown that increasing the stature of the animal results in lower profit.

Finally, consequences of changes made in August 1992 to the milk pricing system were studied by using first lactation profit of cows which calved between January 1980 and December 1988 and between August 1992 and December 1994. The introduction of the multiple-component pricing system had a large effect on economic values attached to protein production. It has been shown that, in the 1980's, economic values for protein were negative in all breeds. After August 1992, its economic value became positive in all breeds and testing programs.

It is important to keep in mind that, in order to build selection indexes, economic values are needed as well as genetic and phenotypic parameters. Economic values are indicators of what selection index coefficients should be, but without any knowledge of heritabilities, genetic and phenotypic variances and covariances of traits, new selection indexes cannot be built. It would be interesting, in future studies, to determine how differences between different sets of economic values affect selection index coefficients and how much the efficiency of selection is modified.

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Appendix

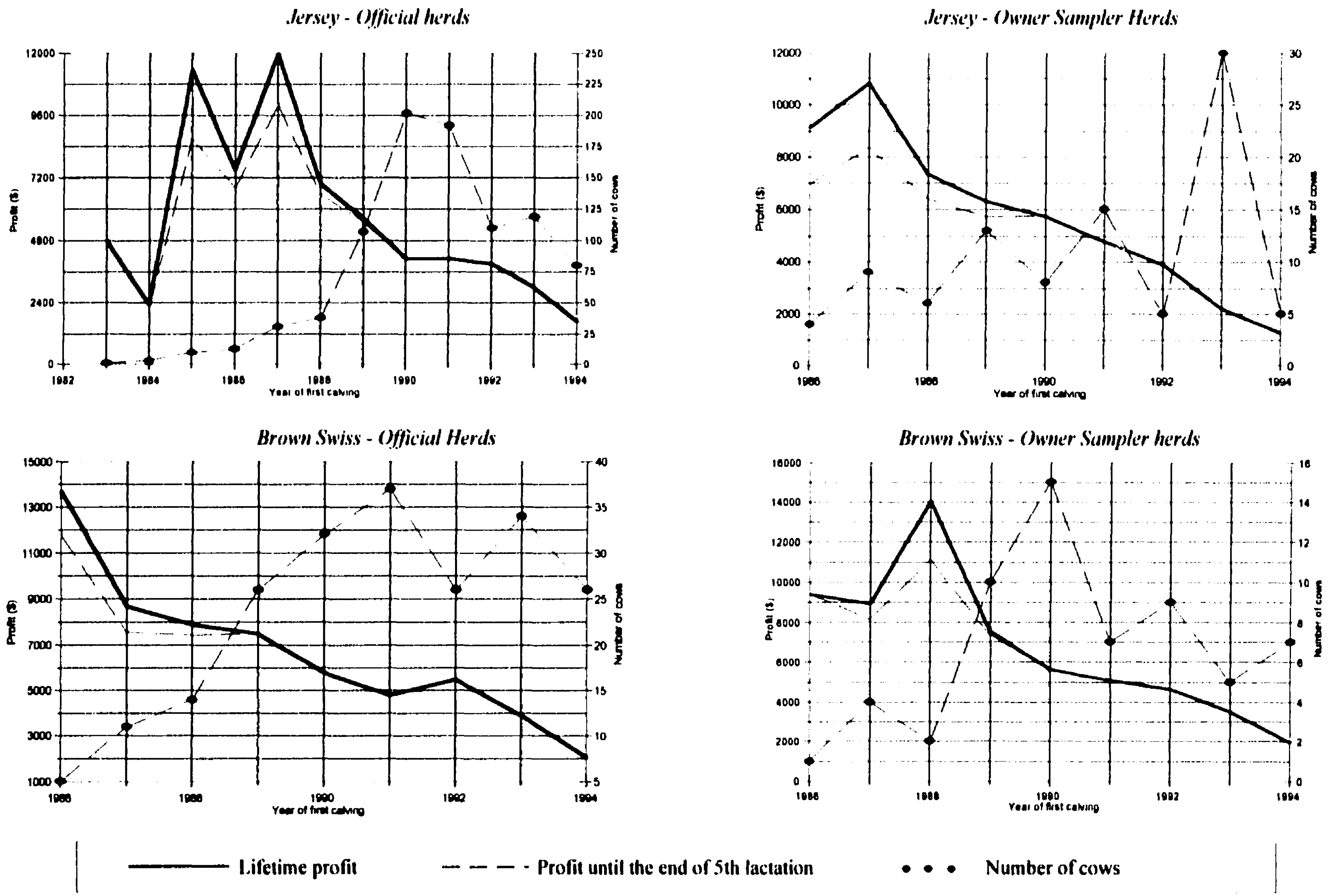
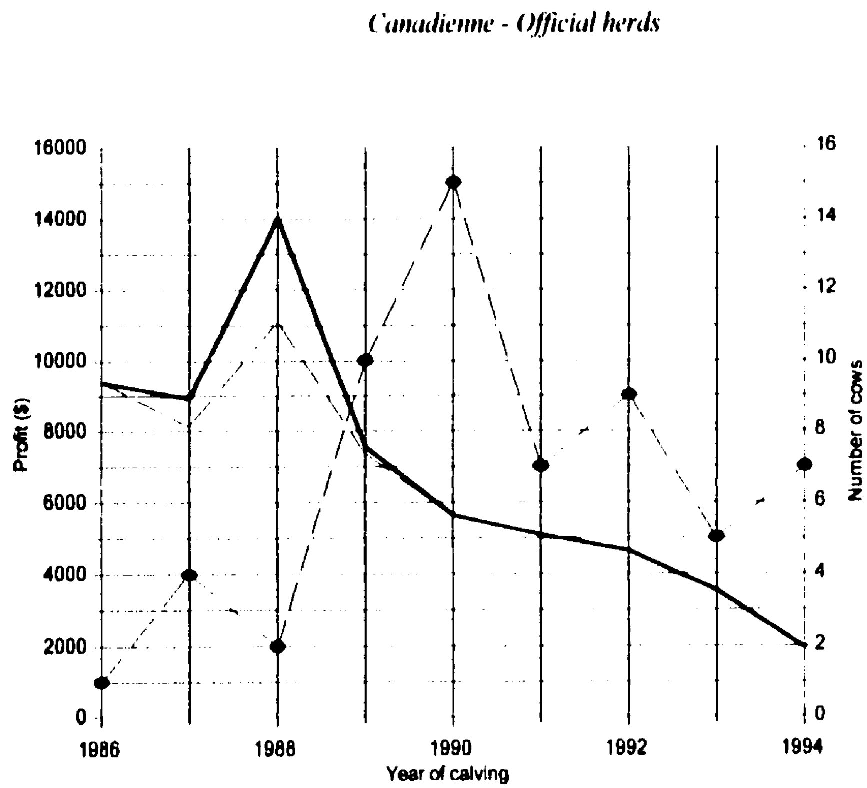
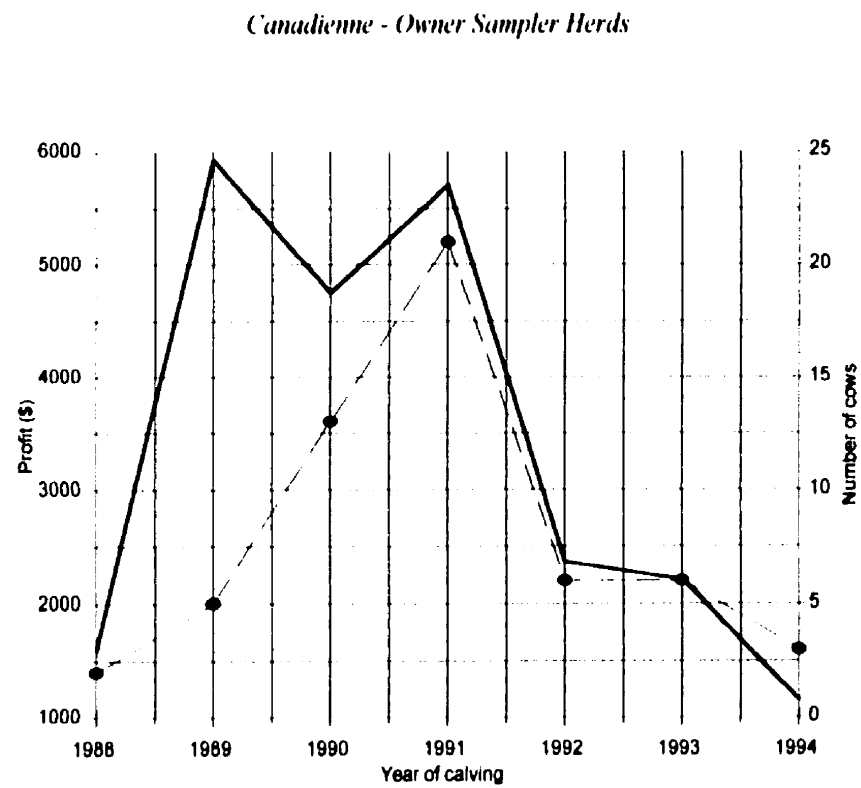


Figure A1 Progression of means of lifetime profit, means of profit until the end of 5th lactation and number of cows by year of first calving





Lifetime profit — — — Profit until the end of 5th lactation • • • Number of cows

Figure A1 (continued) Progression of means of lifetime profit, means of profit until the end of 5th lactation and number of cows by year of first calving

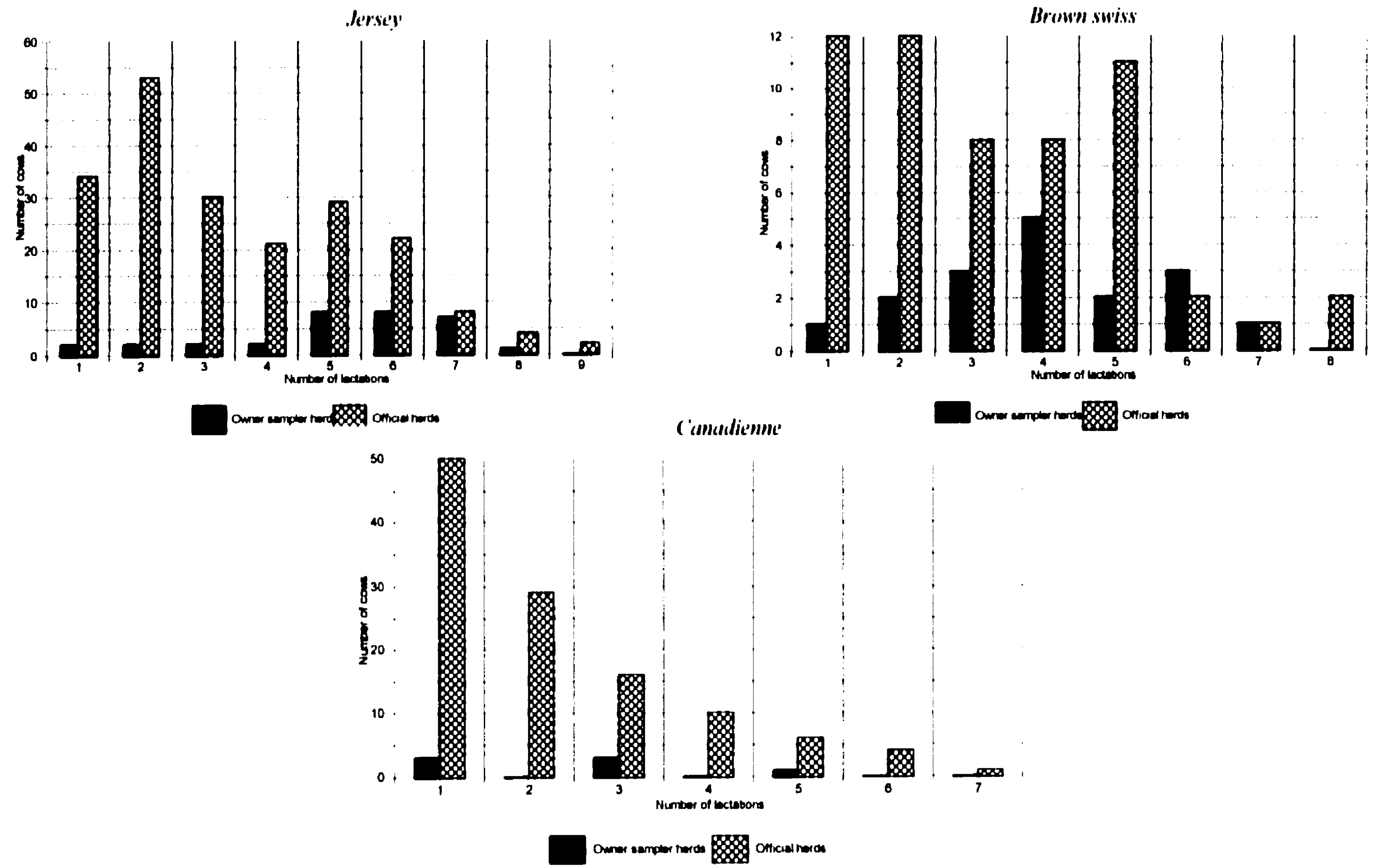


Figure A2 Distribution of cows according to the number of lactation performed

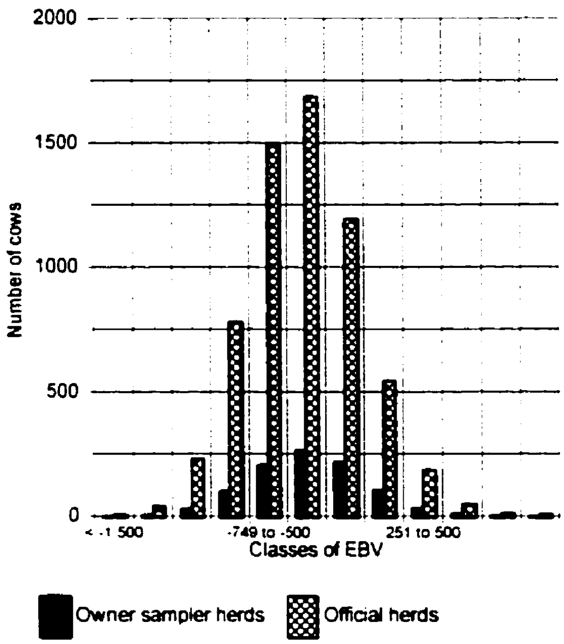


Figure A3.1 Distribution of EBV for milk production for Aryshire

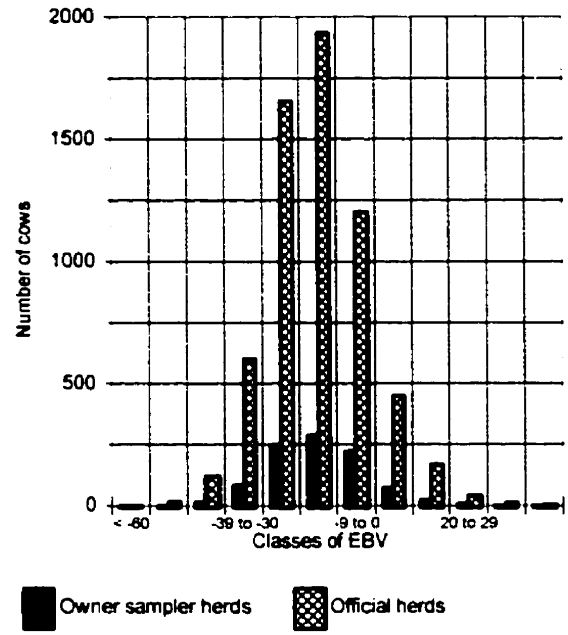


Figure A3.2 Distribution of EBV for fat production for Ayrshire

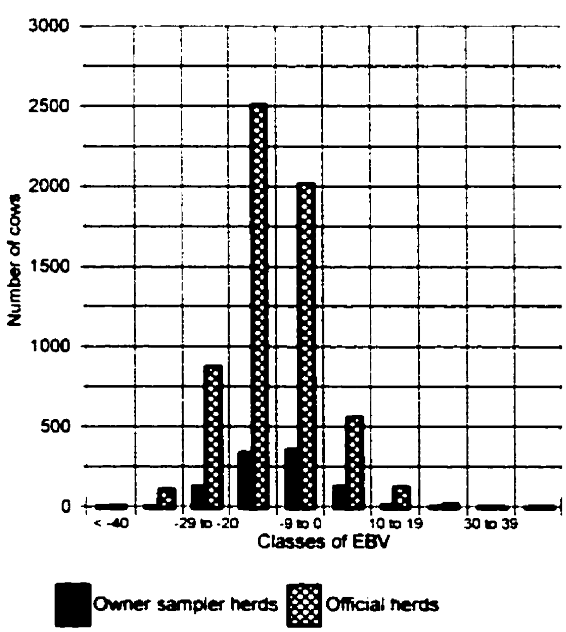


Figure A3.3 Distribution of EBV for protein production for Ayrshire

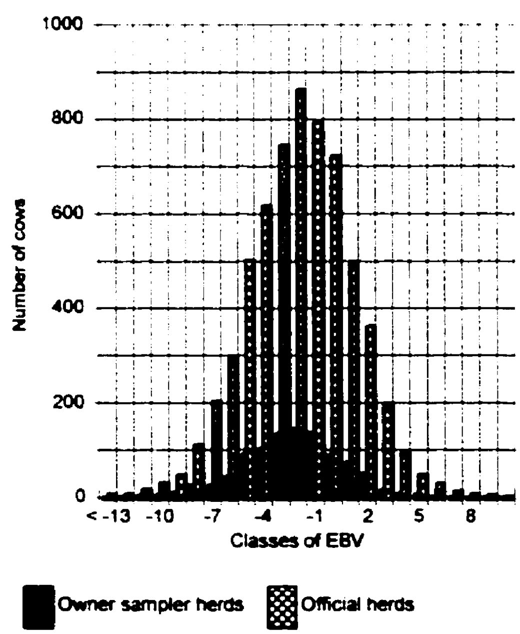


Figure A3.4 Distribution of EBV for conformation for Ayrshire

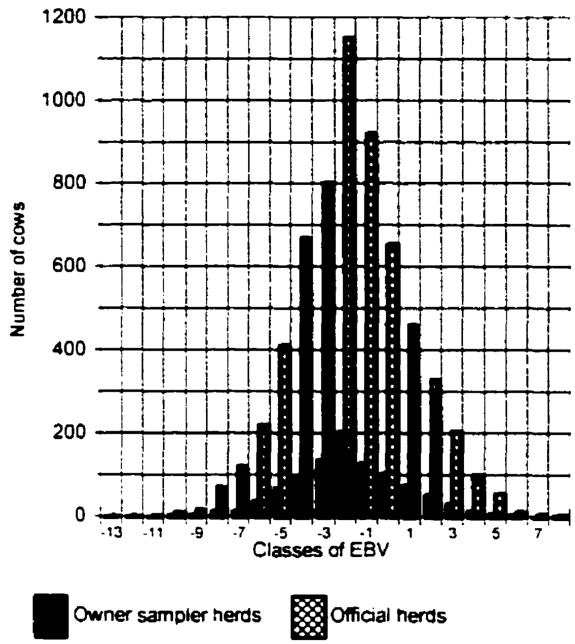


Figure A3.5 Distribution of EBV for capacity for Aryshire

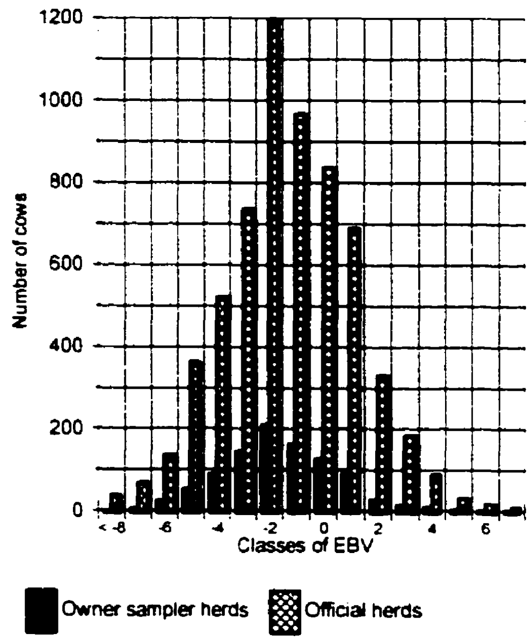


Figure A3.6 Distribution of EBV for feet and legs for Ayrshire

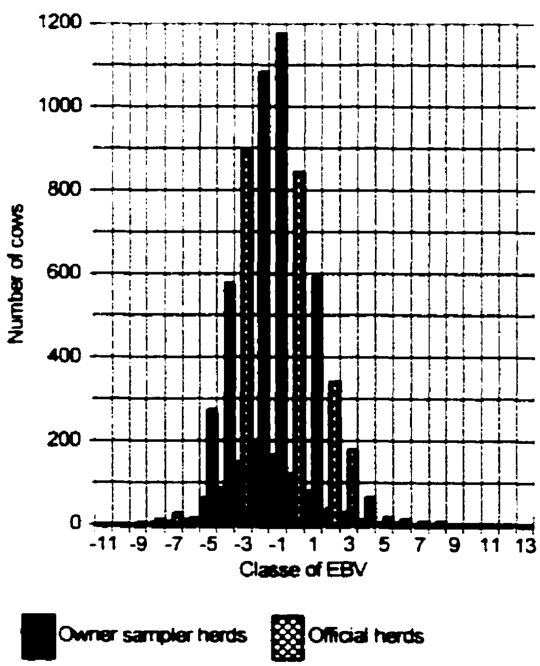


Figure A3.7 Distribution of EBV for mammary system for Ayrshire

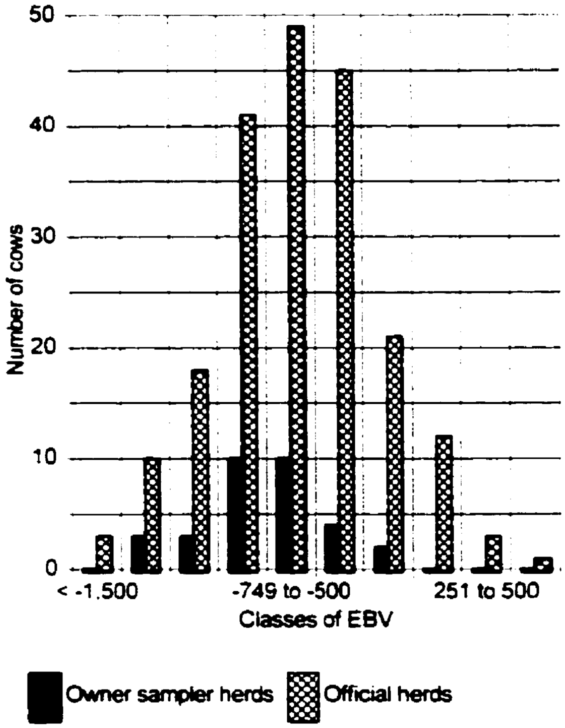


Figure A4.1 Distribution of EBV for milk production for Jersey

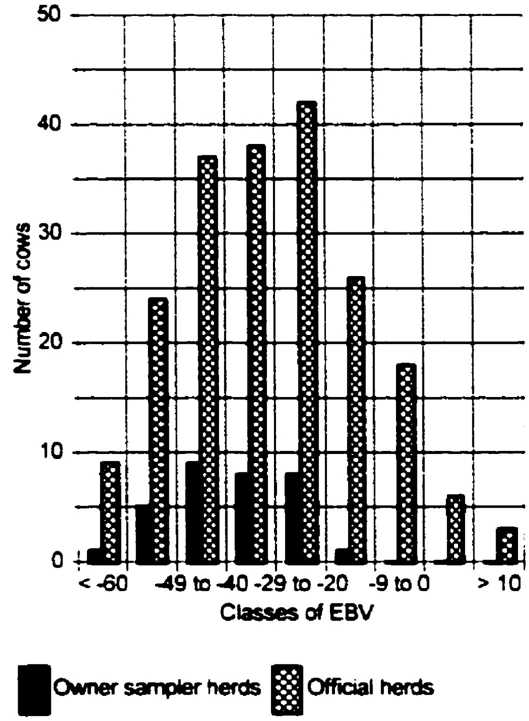


Figure A4.2 Distribution of EBV for fat production for Jersey

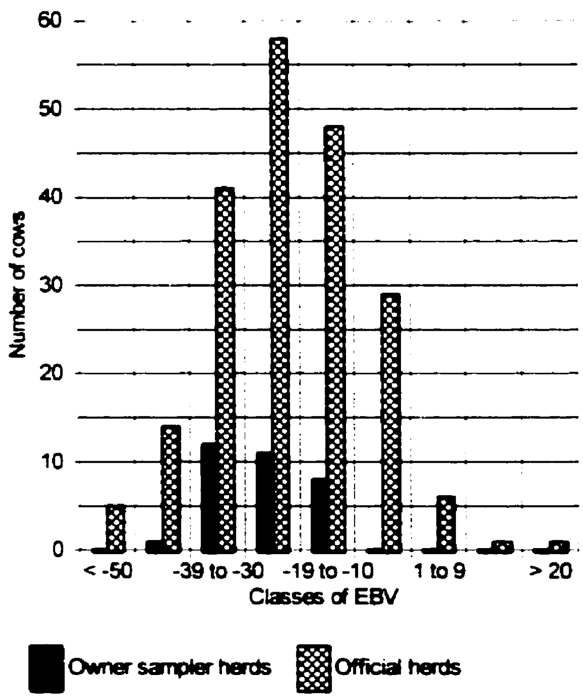


Figure A4.3 Distribution of EBV for protein production for Jersey

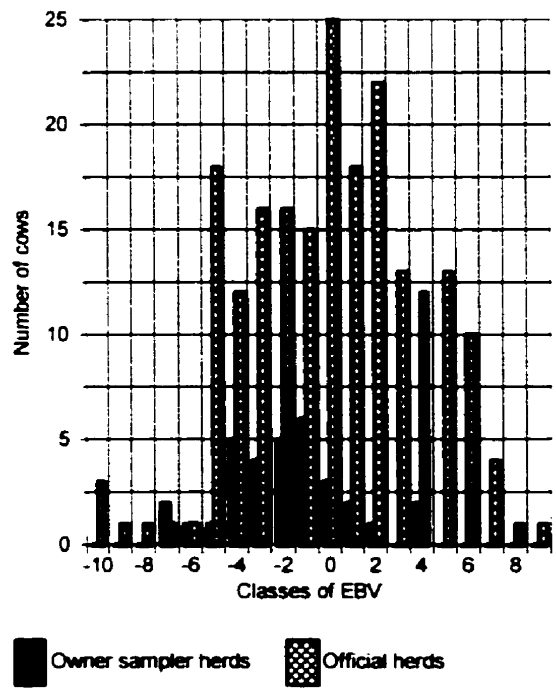


Figure A4.4 Distribution of EBV for conformation for Jersey

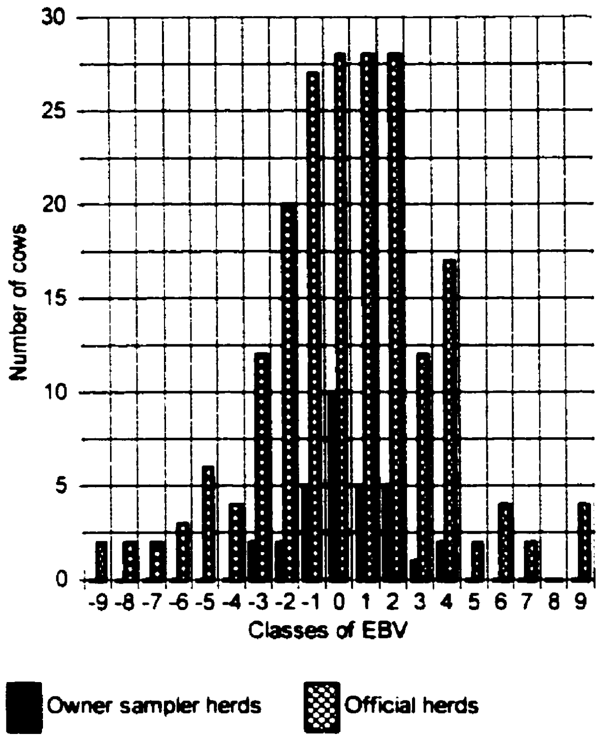


Figure A4.5 Distribution of EBV for capacity for Jersey

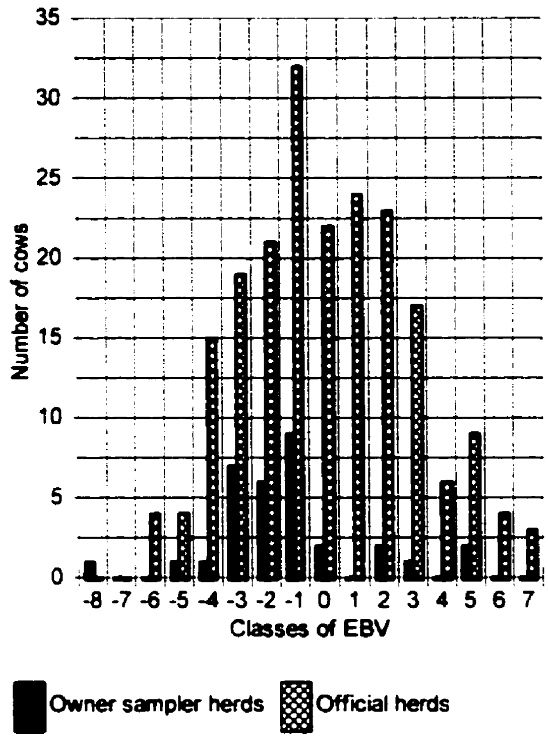


Figure A4.6 Distribution of EBV for feet and legs for Jersey

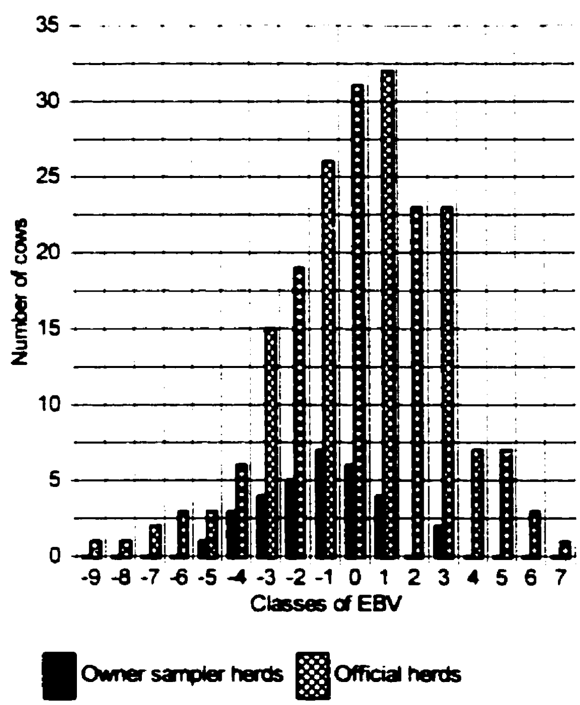


Figure A4.7 Distribution of EBV for mammary system for Jersey

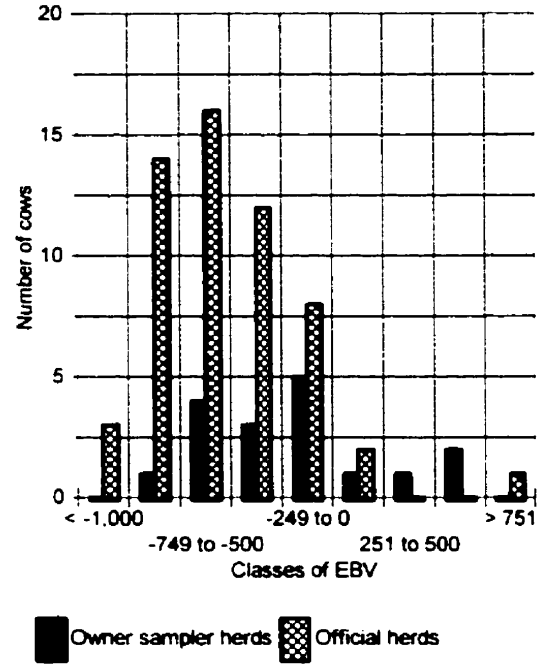


Figure A5.1 Distribution of EBV for milk production for Brown Swiss

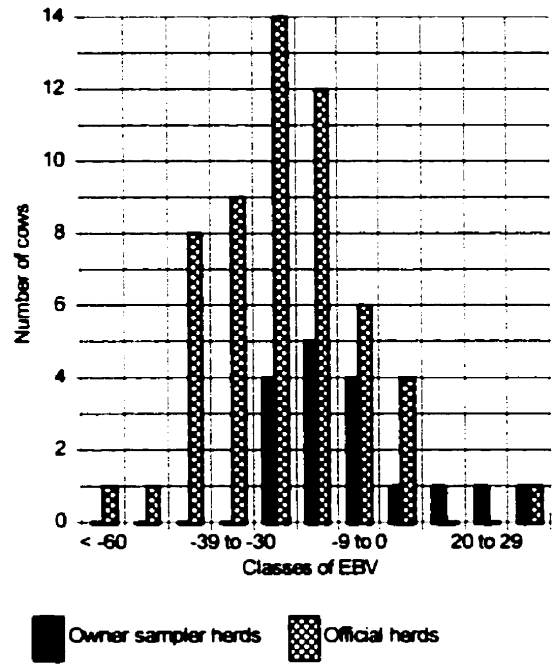


Figure A5.2 Distribution of EBV for fat production for Brown Swiss

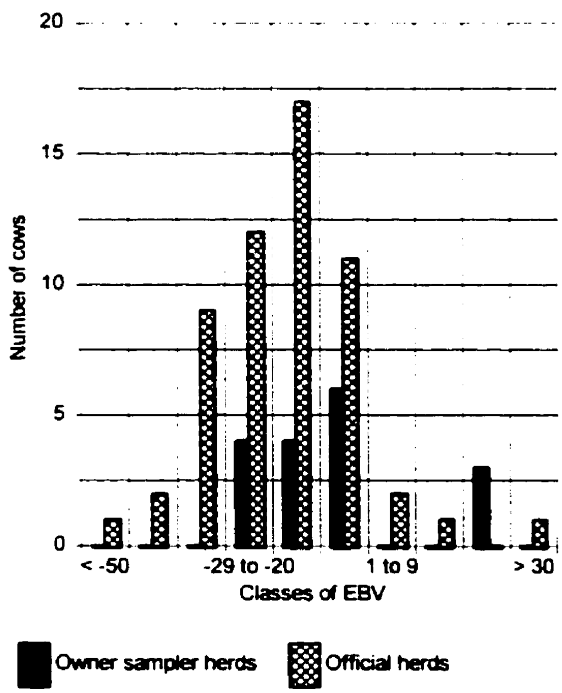


Figure A5.3 Distribution of EBV for protein production for Brown swiss

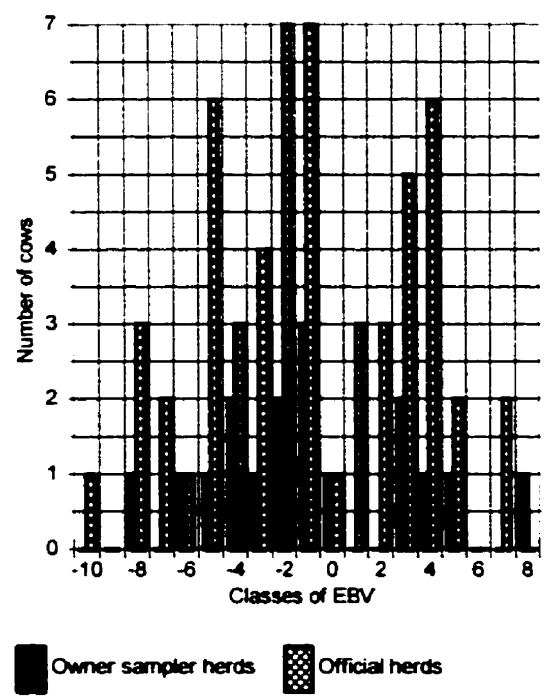


Figure A5.4 Distribution of EBV for conformation for Brown Swiss

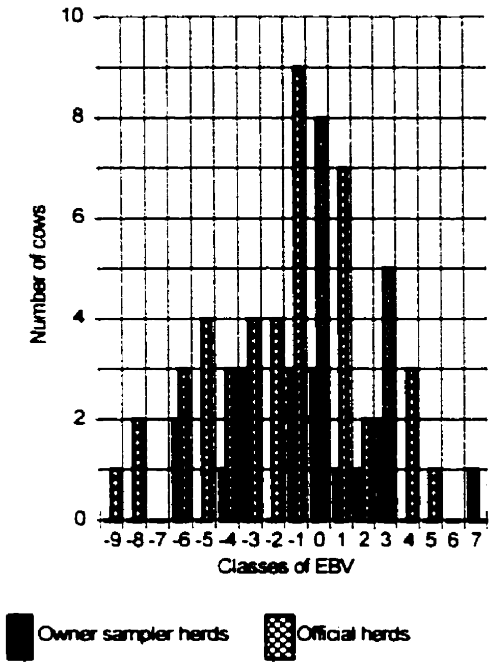


Figure A5.5 Distribution of EBV for capacity for Brown Swiss

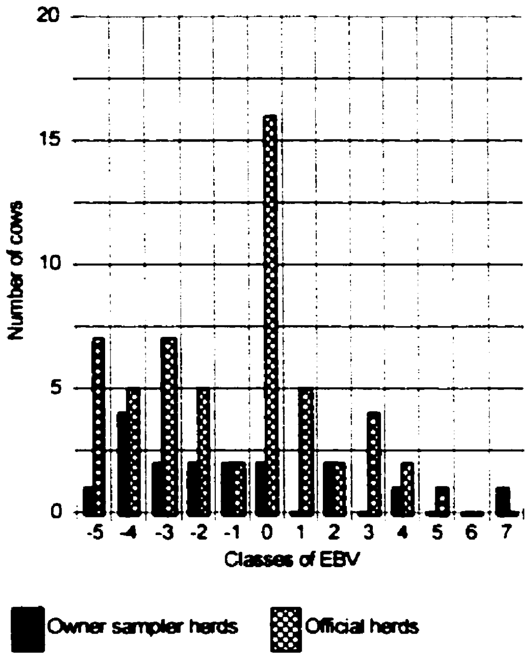


Figure A5.6 Distribution of EBV for feet and legs for Brown Swiss

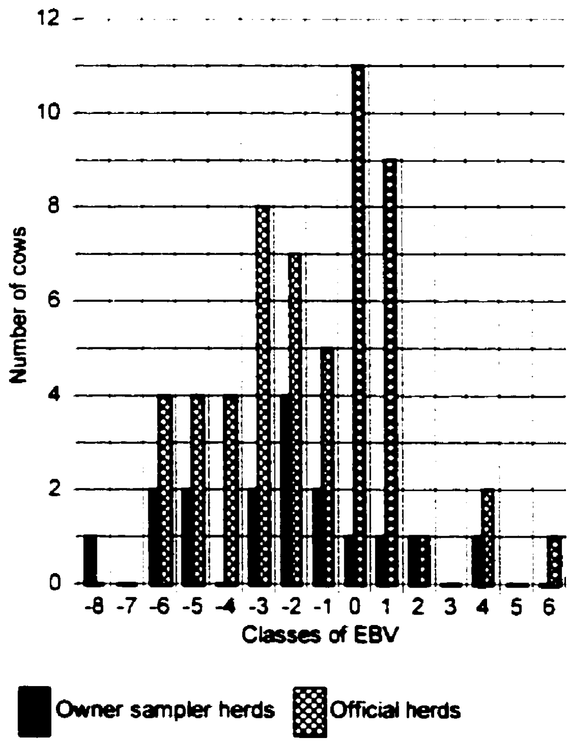


Figure A5.7 Distribution of EBV for mammary system for Brown Swiss

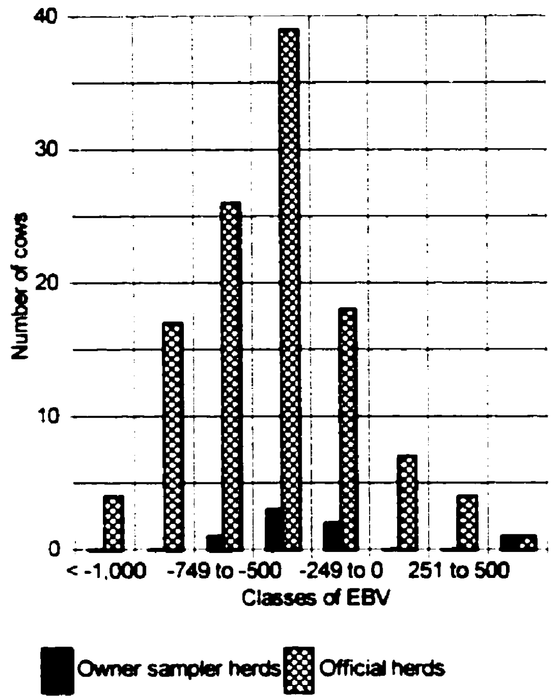


Figure A6.1 Distribution of EBV for milk production for Canadienne

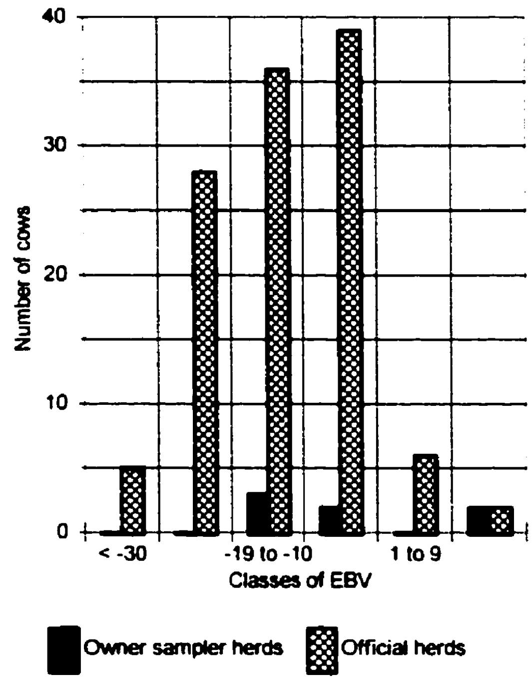


Figure A6.2 Distribution of EBV for fat production for Canadienne

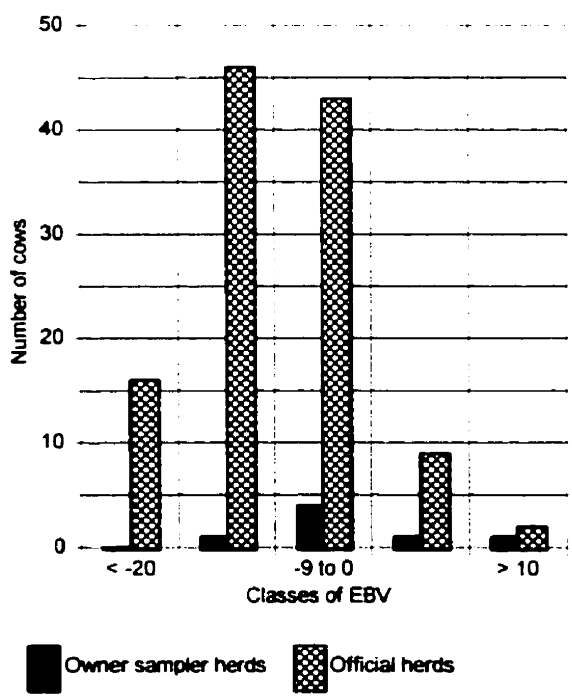


Figure A6.3 Distribution of EBV for protein production for Canadienne