An initial study of the economic values of dairy cattle traits in Canadian Holsteins estimated using random regression models

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ABSTRACT: Economic values were estimated by regressing profit, adjusted for opportunity cost, up to the end of the 4th lactation on EBVs, using random regressions within herd-year cohort of first calving. Kilograms Fat, kg Protein, milking speed, temperament, rump and conformation all had positive economic values, whereas herd life, angularity, somatic cell score and stature had negative economic values. Both mammary system and fat percentage showed significant interactions with Housing system (Tie-stall vs Free-stall). There were significant variances for herd, year and herd-cohort. Random regressions were not statistically significant. Profit not adjusted for opportunity costs showed a significant positive regression for herd-life, as might be expected, whilst stature showed a large negative regression coefficient (economic value).
Keywords: dairy cattle; Economic values; Milk production genetics

Introduction

Efficient selection requires that we know the appropriate economic values to use to correctly weight each trait in a selection index (Haze, 1943). Economic values have been principally estimated using either bio-economic models, or empirically estimated. St-Onge et al (2002) used multiple regression to empirically estimate economic values in Quebec dairy cows. They showed that different groups of producers (Officially Supervised, or Owner-Sampler herds) had different economic values for traits. This suggests that different economic weights might be appropriate for different herds; this has been suggested theoretically in several species and populations, but with little direct evidence. The study of St-Onge et al (2002) did not have access to veterinary recorded lactation health events, such as cases of mastitis, displaced abomasum, etc. Currently, in Canada the main selection index is the Lifetime Profit Index (CDN, 2012). The objective of this study was to estimate economic values when both feed costs and non-feed costs (breeding and health events) were accounted for, and to determine whether there was significant variability amongst herds, i.e. whether individual herd-specific economic weights might be justified.

Materials and Methods

Data. Lifetime profit records for individual cows, for the period January 2000 to the end of December 2012, were calculated from data provided by Valacta, the milk recording agency of Québec, Canada, which data were then merged with veterinary lactation event health data from Données Santé Animale, the Quebec veterinary herd health recording program, developed by the Faculté de Médécine Veterinaire of Université de Montréal. One thousand one hundred herds had both production data from Valacta and identified animals in the DSA database for the time period 2000 to 2012. Lifetime profit was calculated as the lifetime value of milk produced, minus the calculated feed costs (including rearing costs to first calving), breeding costs and veterinary event costs; all these are available on an individual cow basis. Valacta calculates and records individual cow feed costs at each test-day, based on the cow's nutrient requirements (function of production, live weight, parity, stage of gestation and body condition score), the producer's available feeds, their composition and price, and the amount the producer records as being fed. Mastitis costs were calculated as veterinarian costs, drug costs and estimated discarded milk value (obtained from Valacta production records). Other health events treated with drugs similarly considered the value of the discarded milk. For this study we looked only at profit to up to the end of the 4th lactation. Only cows calving for the first time between 2000 and the end of 2007 were retained, to allow all animals the opportunity to complete 4 lactations. Herds were retained only if they had been continuously recording both reproductive events and mastitis events during the period 2000 to 2012. In addition, each herd-cohort year of first calving had to have at least 10 animals; this was to ensure that each herd-cohort had an adequate number of animals and to reduce any problems associated with very small subclass numbers. Various data edits were applied to ensure continuous recording and to eliminate erroneous data. Opportunity costs were calculated as per van Arendonk (1991), and Kulak (1997) and subtracted from lifetime profit, on a per year basis; see Delgado et al (2013). Herds were classified as Free-stall or traditional Tie-stall, and whether they were using Total Mixed Ration feeding, or not. These lifetime records were then merged with the genetic evaluation records for each cow, provided by the Canadian Dairy Network. There were 79 herds with complete health recording, as well as continuous production and feed cost data. For this study only Holstein data were used, since preliminary analyses indicated that there were not enough records from other breeds to be worthwhile. The very substantial reduction in the number of herds available (79 out of 1100) is in line with previous lifetime studies from this group (St-Onge et al, 2002); requiring consistent recording, particularly of health traits does tend to curtail the size of any dataset. There were 10717 lifetime records available, in 571 herd-cohort groups. Table 1 presents descriptive statistics for the cumulative lifetime profit adjusted for opportunity cost (OC Profit), cumulative lifetime profit (no adjustment for any opportunity costs: Cum. Profit), cumulative lifetime mastitis costs (Mastitis Cost), cumulative lifetime milk value (calculated from test day milk composition and component prices: Milk Value) and cumulative feed costs (calculated by Valacta and based on monthly feed formulations and including heifer rearing costs: Feed Costs). Table 2 shows the trait names and a brief explanation of the various EBVs which were statistically significant and which were used as the fixed and random regression covariates. Approximately 2/3rds of the records were from traditionally fed herds and 1/3rd from TMR-fed herds; 3/4qtrs of the records were from Tie-stall housed animals and 1/4qtr from Free-stall housed animals.

Table 1. Descriptive statistics for lifetime measures to the end of the 4th lactation.

	OC Profit	Cum. Profit	Mastitis Costs	Milk Value	Feed Costs
Mean	-.970	7.968	.147	15.263	3.677
Min.	-12.828	-4.068	0	.036	.009
Max	20.529	38.705	6.628	52.803	12.781

Table 2. Traits (Estimated Breeding Values) used as regression effects.

Trait	description
EBVfatkg	EBV for kg of fat
EBVprotkg	EBV for kg of protein
EBVfatpc	EBV fat percentage
EBVhl	EBV for herd life
EBVmsp	EBV for milking speed
EBVmt	EBV for milking temperament
EBVscs	EBV for somatic cell score
EBVconf	EBV for overall conformation
EBVstature	EBV for stature
EBVmammary	EBV for mammary score
EBVangularity	EBV for angularity
EBVrump	EBV for rump

Model. Lifetime profit (OCProfit), Cumulative lifetime profit (Cum. Profit) and Cumulative Mastitis Costs (Mastitis Cost) were each regressed on estimated breeding values [EBVs] (fixed effects), as well as random regressions, on EBVs, specific to each herd-cohort year of first calving. Data were analysed using SAS v9.3 and R (v3.0.2, and package lmerTest).

The basic model was:

$$\text{Trait}_{jk} = b_0 + \text{Housing} + \text{TMR} + \sum b_i * \text{EBV}_{ijk} + \sum b_{ij} * \text{EBV}_{ijk} + e_{ijk}$$

where Housing is the effect of either Tie-stall or Free-stall, TMR is the fixed effect of either traditional feeding systems, or Total Mixed Rations, b_i is the fixed effect regression coefficient of the regression of profit on the EBV of the ith trait (Kg. fat, Kg. protein. etc) of the kth cow from the jth herd-cohort year of first calving, and b_{ij} is the random regression coefficient of the ith variable from the jth herd-cohort. In addition fixed effect interactions between housing system (Tie-stall vs Free-stall) and regression on EBVs, and between Feeding system (TMR vs traditional) and regressions on EBVs were also initially included, to test whether different economic weights would be appropriate for different types of defined management systems (housing and feeding systems).

The average cumulative profit, to the end of the fourth lactation (hereafter called lifetime profit) was 7968$, ranging from a minimum of -4068$ to a maximum of 38705$ (Table 1, note all values have been divided by 1000). Average lifetime profit, adjusted for opportunity cost, was -970$, with a minimum of -12828$ and a maximum of 20529$. Lifetime cumulative mastitis costs ranged from 0$ to a non-trivial maximum of 6628$.

Results and Discussion

All the traits for which CDN provides estimated breeding values (production, type and various auxiliary traits) were initially included as fixed and random regression covariates, as well as their interactions with the fixed classification effects of Housing and Feeding (TMR), using the lmerTest package of R (version 3.0.2). The estimated economic values (the coefficients of regression of profit on EBVs) are shown in Table 3. Only regression coefficients which were statistically significant at the 5% probability level were retained in the model and are shown in Table 3. The regression of Opportunity Cost adjusted Profit (OCProfit) on EBV fat kg was 0.0434, which since profit was re-scaled by dividing by 1000 implies that the lifetime profit is expected to increase by 43.4$ for each unit increase in the EBV for kilograms of fat. Somatic cell score had a large negative economic weight, as might be expected; increasing somatic cell counts (scores) are associated with lower overall production and hence profitability. The imputed economic value was -1632$ per unit EBV. Stature had a negative economic value (the regression coefficient was -0.0301, which translates to -30.1$ per unit EBV). Both of the estimated economic values (for somatic cell score, and for stature) are logically reasonable. A higher EBV for somatic cell score implies higher somatic cell counts which are costly in terms of direct health and veterinary costs and discarded milk value, and may also have longer-term carry-over effects on the subsequent part of a cow's lactation and possibly subsequent lactations. This can also be seen in the statistically significant regression of Cumulative Lifetime Mastitis Costs (direct and discarded milk value) on EBVscs. The negative economic value for stature implies that for cows with the same production potential (fat and protein) that for bigger cows (i.e., those with a larger stature) the profit will be less; this is entirely reasonable, since larger body size implies extra maintenance costs. This negative value attributed to stature is consistent with the results obtained by St-Onge et al (2002), and with the negative economic weights attributed in New Zealand and by the USDA AIPL Net Merit$ index (Cole et al, 2010). For both mammary system and fat percentage the regression coefficients on EBV differed significantly between Housing systems (Tie-stall vs Free-stall), indicating that different economic weights would be appropriate for these two traits, depending upon the producer's type of housing system. For heterogeneity amongst herds with respect to regression coefficients (the random regression coefficients concept outlined in the introduction), none were statistically significant, at the 5% probability level, but there was some indication of a possible heterogeneity for an effect of feet & legs. Such heterogeneity would suggest that herd-specific economic values might be appropriate.

Table 3. Regression coefficients (b_i) for fixed effects.

Variable	OC Profit b_i	Cum Profit b_i	Mastitis Cost b_i
EBVfatkg	.0435	.0748	n.s.s.
EBVprotkg	.0267	.0682	.0013
EBVhl	-.0202	.1116	.0055
EBVmsp	.0382	.0680	n.s.s.
EBVmt	.0229	.0689	n.s.s.
EBVscs	-1.632	-4.975	.2298
EBVconf	.0803	.4622	n.s.s.
EBVstature	-.0301	-.0832	n.s.s.
EBVangularity	-.0359	-.1862	n.s.s.
EBVmammary (Tie)	-.0132	-.0805	.0052
EBVmammary(Free)	-.0847	-.2379	-.0042
EBVfatpc (Tie)	-1.054	-2.948	n.s.s.
EBVfatp (Free)	-1.522	-3.553	n.s.s.

When cumulative profit (not adjusted for opportunity costs) was regressed on the various EBVs the regression coefficients tended to be larger in absolute value. However, the economic value of herd life was the only one which changed in both magnitude and sign, from -0.0202 to 0.1116. The small negative economic value for herd life, when looking at profit adjusted for Opportunity Cost, can be explained in terms of the partial regression coefficients: the regression on herd life is over and above production, conformation, etc. The small negative value, therefore, suggests that increasing herd life, in addition to any increased production, translates into a greater opportunity and probability of contracting cases of mastitis or other health-related traits, thereby increasing costs, and hence the small negative value. For the unadjusted profit (the simple Cumulative Profit), since it does not correct for opportunity cost, the value of herd life can (amongst other things) amortize rearing costs over a greater number of lactations, and hence provide a positive economic value. It should be noted that these analyses and models do not include EBVs for mastitis or other health-related traits, and this may be part of the explanation for the contrasting economic value estimates. Their inclusion would be expected to further change the economic value of herd life, thus illustrating the complexity of properly estimating these important management factors.

Conclusion

These results suggest that the economic values to attribute to traits may vary across herds, or types of herds. It may be sensible to investigate further whether customized selection index weights may be warranted for specific herds.

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